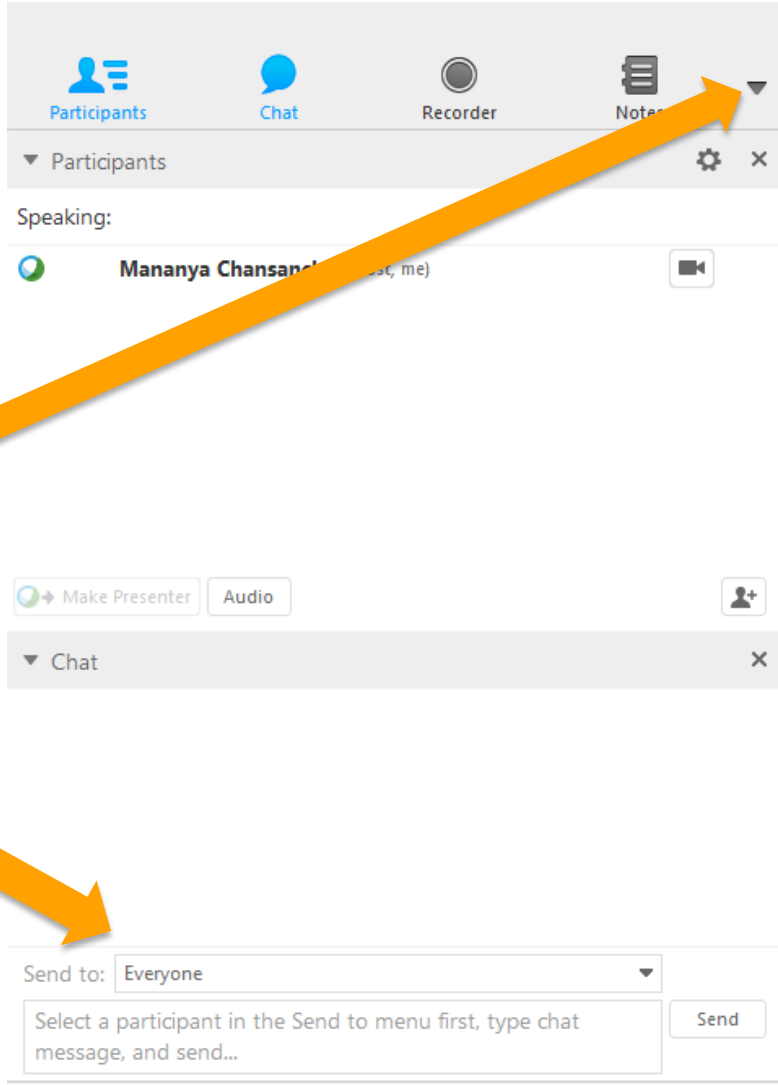
CA | Energy Efficiency Strategic Plan

LIGHTING ACTION PLAN STAKEHOLDER MEETING October 20, 2015

Webinar Participants

- Quick logistics
  - Phone lines are muted (will be unmuted for Q&A)
  - Minimize control panel
  - Webinar will be recorded
  - Please use chat feature to ask questions during Q&A or if any technical issues



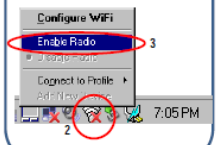
Connectivity

- WiFi:
  - Geco Network
  - Key: 53982064

Connecting to Guest Wi-Fi via PC

A – Enable WiFi

1. Obtain guest Wi-Fi password key at http://wifi. Write this password down before connecting to Guest Wi-Fi.
2. On the bottom right hand corner of your desktop, right click on the wireless utility icon
3. Select "Enable Radio"
4. Wait for the icon to turn green to confirm it is enabled



B – Enter Password

1. Double click the wireless utility icon to launch list of available network.
2. Select the wireless network: geco
3. Enter in the guest Wi-Fi password and click "OK"

C – Accept Terms and Conditions

1. Using your internet browser, open a new browser window.
2. Review and accept the terms and conditions.
3. Complete the PG&E Guest Wireless Registration form (Name, e-mail and telephone number)
4. Click "Submit"

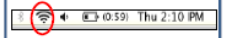
D – You Are Connected!

1. Congratulations! You are now connected and can access the internet.
2. For questions on Guest Wi-Fi, contact the TSC at x223-9000.

Connecting to Guest WiFi via Mac

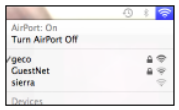
A – Enable WiFi

1. Obtain guest Wi-Fi password key at http://wifi. Write this password down before connecting to Guest Wi-Fi.
2. On the top right corner in the Finder, right click on the wireless icon and select Airport On.



B – Enter Password

1. Double click on the wireless network: geco
2. Enter in the guest Wi-Fi password and click "Connect"



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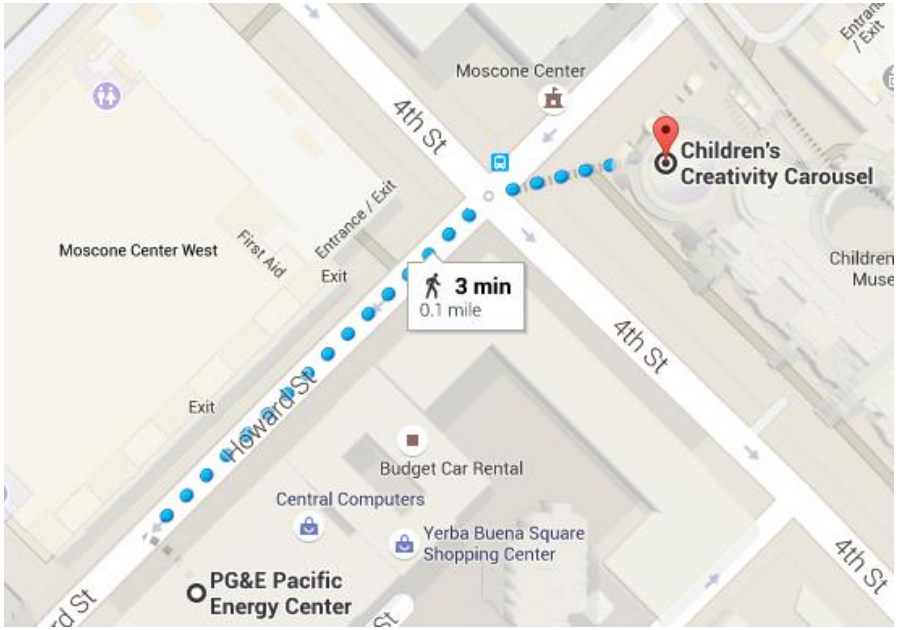
Please try to be engaged!

Safety Announcement

Safety

- In the event of an emergency:
  - Earthquake
  - Fire
  - Other evacuation
- Meeting point: Yerba Buena Carousel @ 4th and Howard
- 911
- CPR Certified?



Verify CPUC Attendance

Overview of the Day

Time	Topic	Expected Outcome
9:30a – 10:00a	**Introduction, Background, and Meeting Overview** *(Jeorge Tagnipes, CPUC and Jenna Canseco, DNV GL)* - Brief introductions - Review of meeting objectives, scope, process	- Ability to work together on a first-name basis - Understand workshop objectives
10:00a – 10:30a	**CPUC Regulatory Update** *(Jeorge Tagnipes, CPUC)* - Review recent and pending decisions and their implications for the LAP	- Understand context and background for LAP
10:30a – 11:00a	**California Lighting Data** *(Jenna Canseco, DNV GL and Priya Sathe, Itron)* - Review available data from lighting retailer shelf surveys, CLASS, and CMST	- Awareness of data/tools available to industry
11:00a –11:45a	**Lighting Technology Overview (LTO) Presentation** *(Nicole Graeber, CLTC)* - Review updated LTO document	- Understand updates to this important document

12:15p – 1:00p	**Advanced Lighting Control Systems (ALCS) Calculator** *(Dave Alexander, PG&E)* - Review PG&E's activities regarding this tool	- Understand purpose and functionality of tool
1:00p – 2:00p	**Networked Lighting Systems** *(Gabe Arnold, DesignLights Consortium and Angi Xanders, DNV GL)*	- Understand current activities inside and outside of California
2:00p – 3:30p	**Breakout Sessions – Program Delivery Strategies for Networked Lighting Systems** *(Jenna Canseco, DNV GL)* - Create brief list of possible program strategies for California IOUs	- Generate program strategies for discussion
3:30p – 4:00p	**Report Back from Breakout Sessions** *(Jenna Canseco, DNV GL)*	- Review strategies and provide feedback
4:00p – 4:15p	**Workshop Wrap-Up and Next Steps** *(Jeorge Tagnipes, CPUC)*	- List of action items and assignments

Meeting Objectives/ Process for Breakout Sessions

Introductions

Regulatory Update

CPUC Regulatory Update
Lighting Action Plan

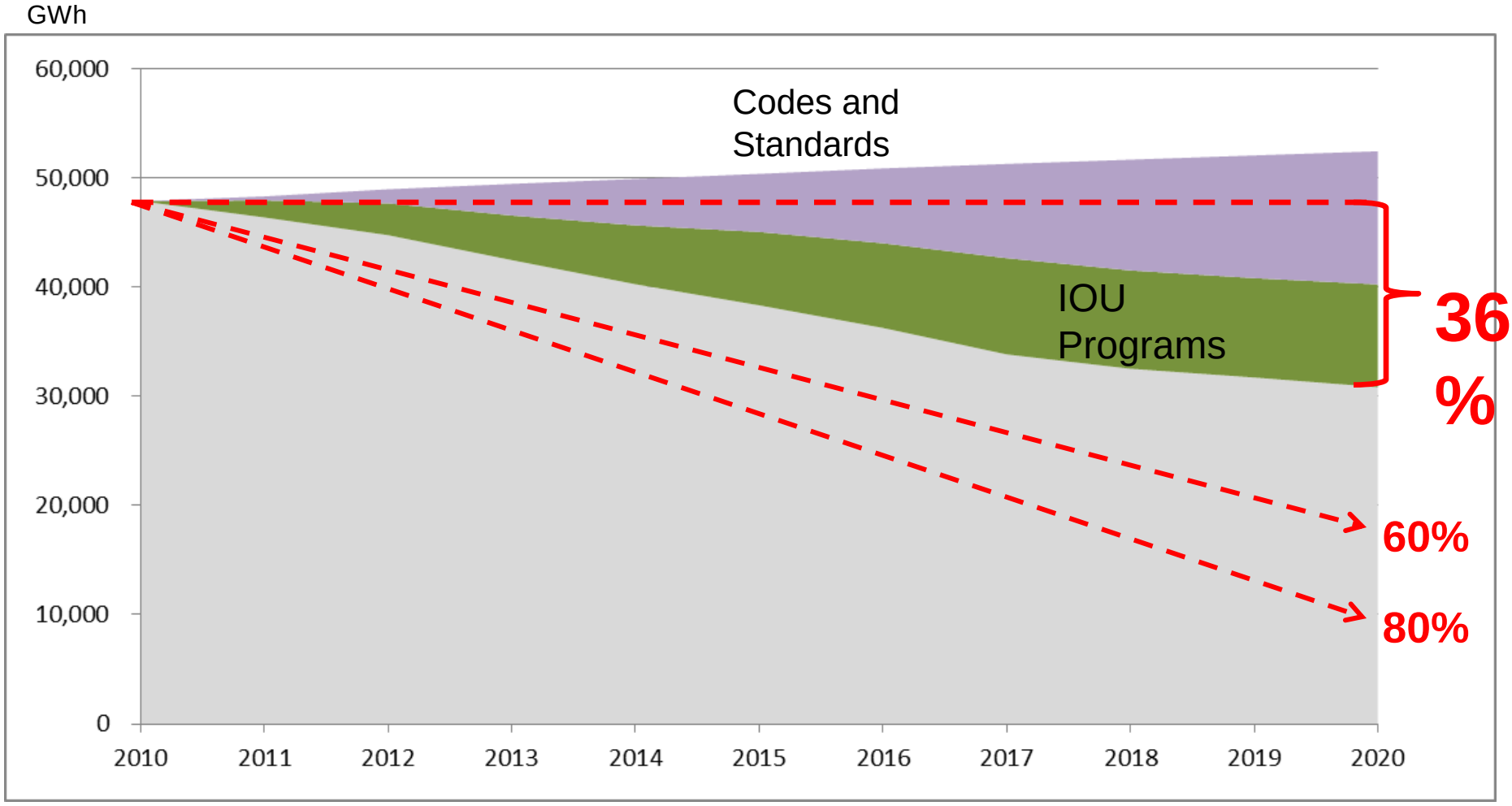
Tuesday, October 20, 2015

Energy Division
California Public Utilities Commission (CPUC)

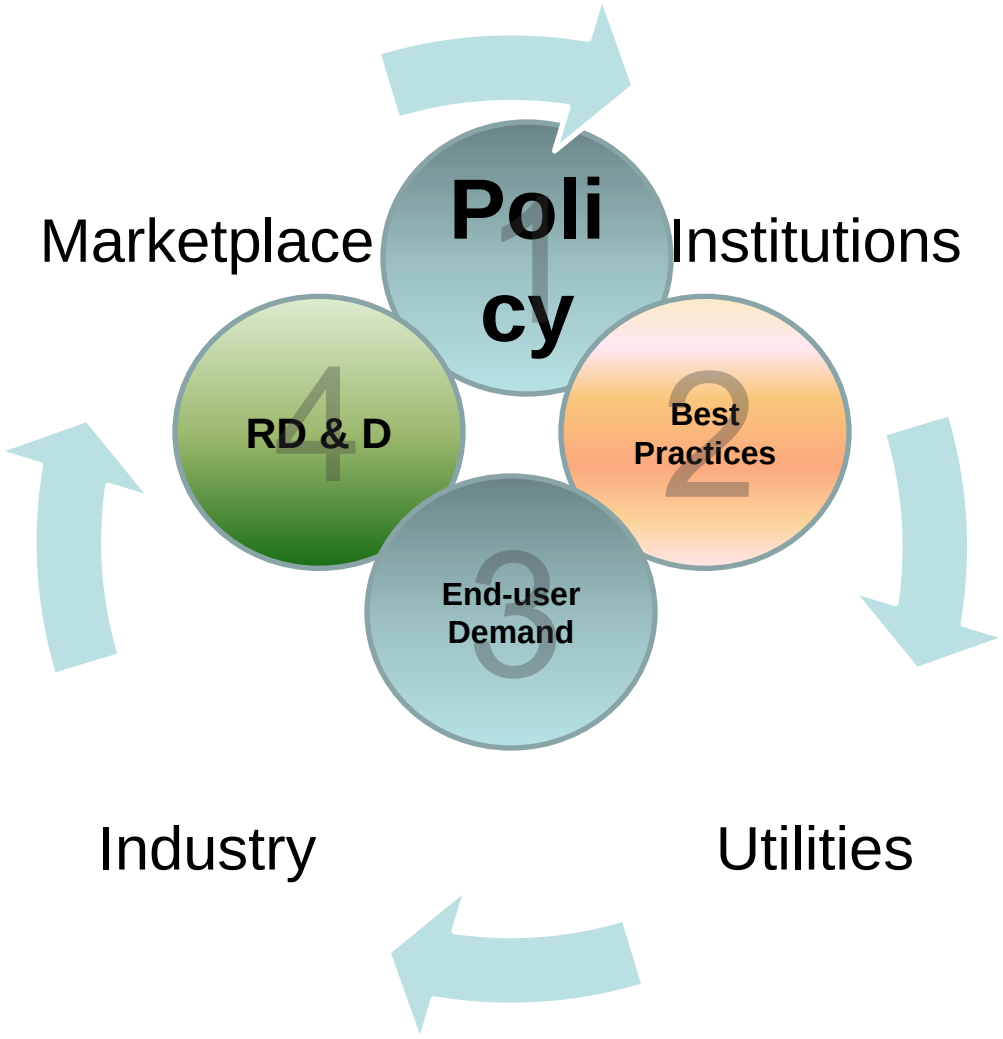
Where We Left Off…

"By 2020, advanced products and best practices will transform the California lighting market. This transformation will achieve 60 – 80% reduction in statewide electrical lighting energy consumption by delivering advanced lighting systems to all buildings."

Where We Left Off….

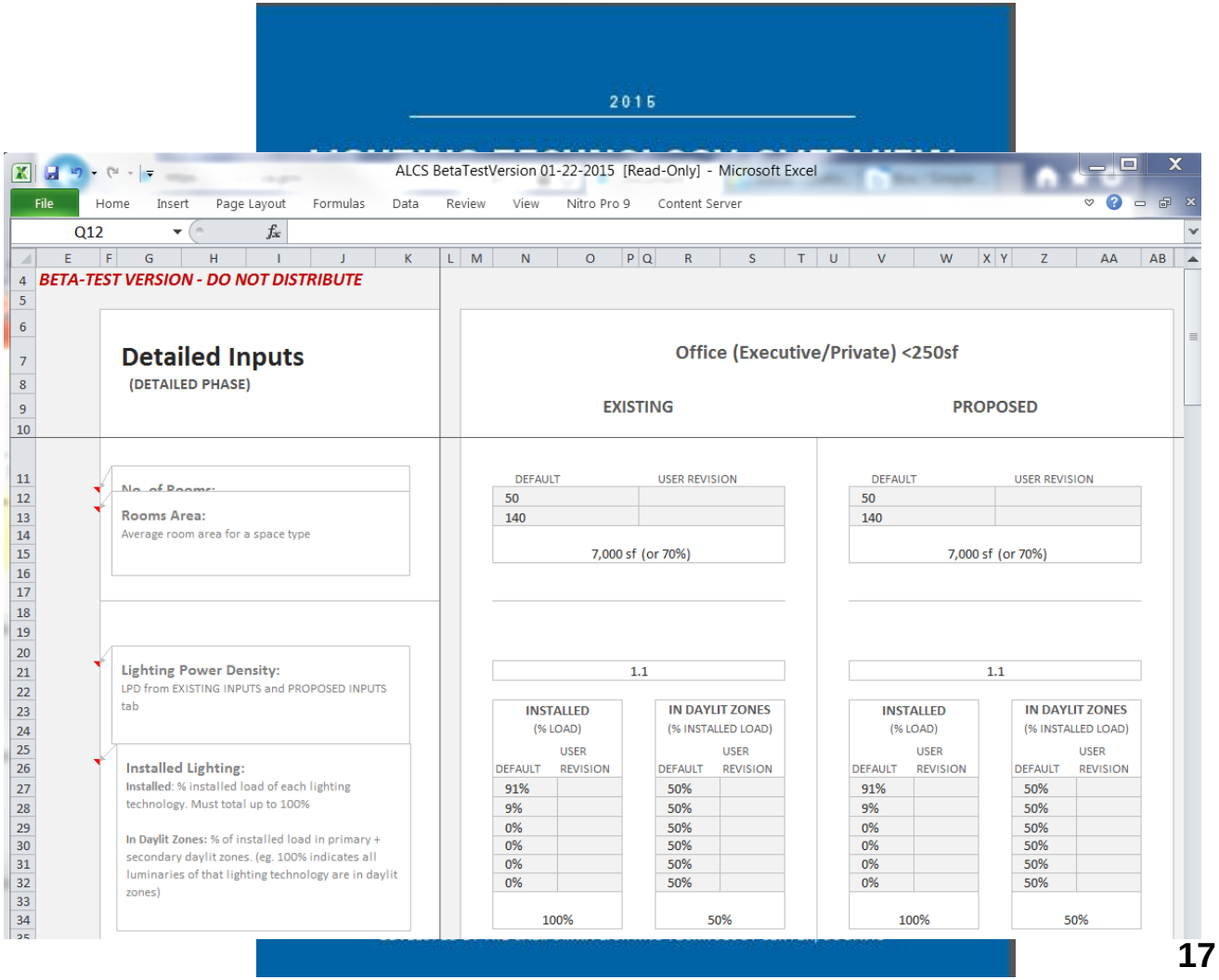


Where We Left Off…



Updates on Initiatives

Goal 2 – BEST PRACTICES



Updates on Initiatives

DNV·GL

t Programs for

DESIGNLIGHTS® CONSORTIUM

National Approaches to Networked Lighting Systems

DLC's CALC Project and Examples from Outside California

October 20, 2015

Evaluation Update

Before …

Year 1

- Guidance decision
- Applications
- Authorizing decision

Year 2

- Implement Programs
- Plan Evaluation

Year 3

- Implement Programs
- Start Evaluations

Year 4

- Guidance decisions
- End Evaluations

Year 5

- Apply evaluation results to Year 2 and 3
- Start new programs

Rolling Portfolio

10 years of funding

10 year annual goals

Rolling Portfolio

J F M A M J J A S O N D

Programs Implemented

On-Going EM&V

EM&V Bus Stop

DEER Updates

DEER Update Bus Stop 9/1

Administrators Update & Inform Implementers Portfolio planning

Quarterly Stakeholder Meeting

Quarterly Stakeholder Meeting

Quarterly Stakeholder Meeting

Quarterly Stakeholder Meeting

Policy and Portfolio Guidance

Portfolio Guidance (when necessary)

Annual Advice Letter 9/1**

Commission Review of AL
AL approved by end of year

Legislation

AB 802 *(Williams)*

Existing baseline

SB 350 *(De Leon)*

Doubling efficiency

California Lighting Data

California Lighting Data – Residential

Retail lighting stock inventory data and California Lighting and Appliance Saturation Study (CLASS) data

Jenna Canseco, DNV GL

October 20, 2015

Lighting Action Plan Meeting

California Retail Lighting Stock Inventory Data

("California Retail Lighting Shelf Survey" [CRLSS] online tool)

What's Included?

- Lighting retail store shelf surveys involve visits to retail stores to record comprehensive inventories of the lamps stocked in those stores
  - Enhance understanding of consumer choices in retail stores
- Information includes:
  - Retail channel
  - IOU service territory
  - Lamp style (form factor)
  - Wattage
  - Lumens
  - Price
  - Package counts
  - CRI
  - Energy Star qualification
  - For LED lamps, whether the lamp meets the CEC spec

What's Included?

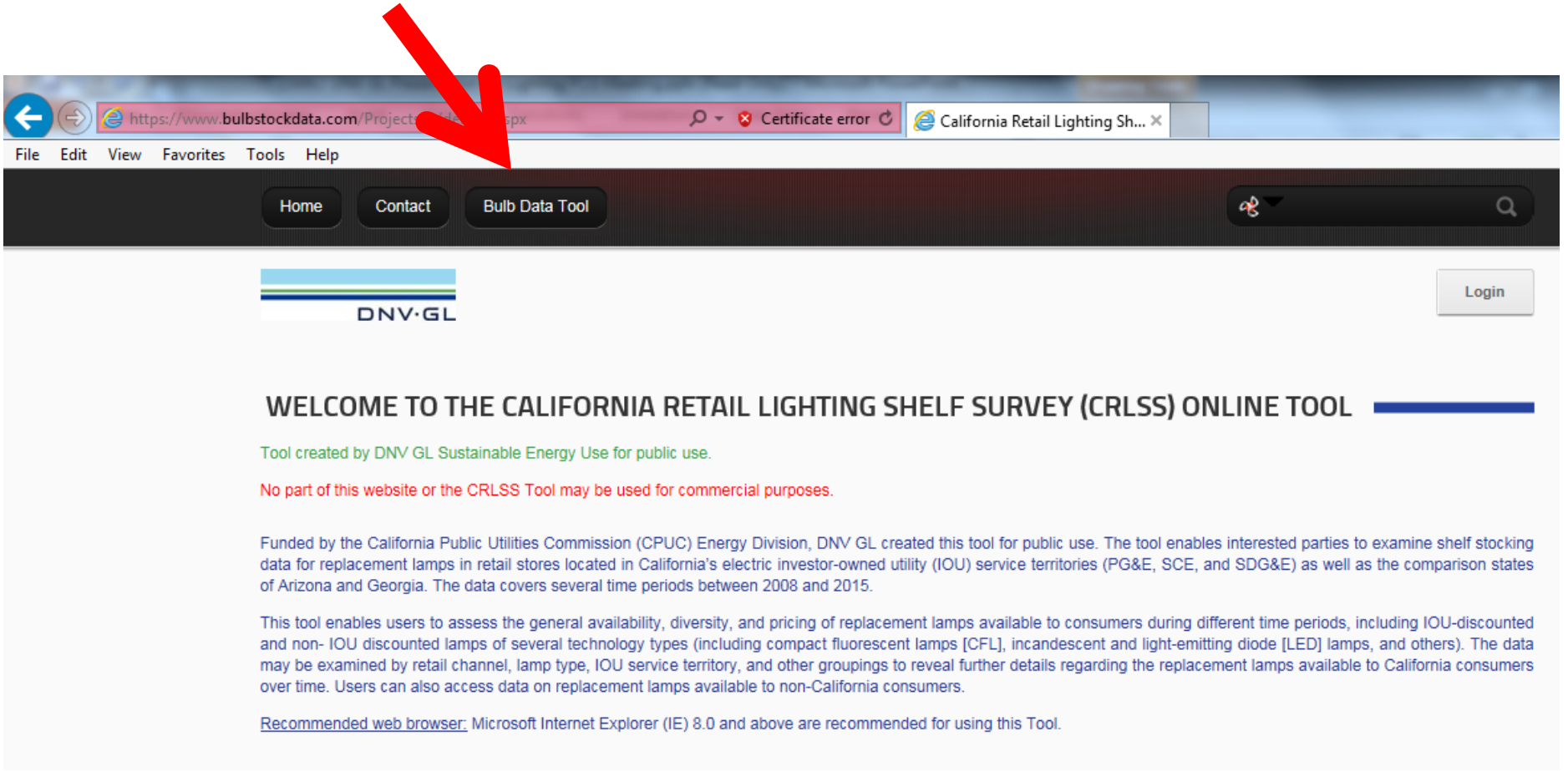
- Data from several different timeframes over an 8-year period
- Will add data from Winter 2015-2016 during Q2 2016

Location/Timing	Number of Stores	Data Collected
CA Spring 2008*	123	9-30Watt medium screw base (MSB) spiral CFLs (non-dimmable, single wattage) and incandescent equivalents (no package counts)
CA Fall 2008	202	All MSB CFLs and incandescent equivalents (no package counts)
CA Spring 2009A	76	All MSB CFLs and incandescent equivalents (no package counts)
CA Spring 2009B	48	Full lighting inventory and package counts of lamps
CA Fall 2011	184	Full lighting inventory and package counts of lamps
CA Summer 2012	200	Full lighting inventory and package counts of lamps
AZ & GA Fall 2012	150	Full lighting inventory and package counts of lamps
CA Winter 2012-2013	200	Full lighting inventory and package counts of lamps
CA Summer 2013	201	Full lighting inventory and package counts of lamps
CA Winter 2014-2015	200	Full lighting inventory and package counts of lamps

* Data collected in PG&E and SCE territories only.

How to Access the Data

- Visit www.bulbstockdata.com
- Click on "Bulb Data Tool"



Demo

- Accessing the site
- Querying data
- Downloading results

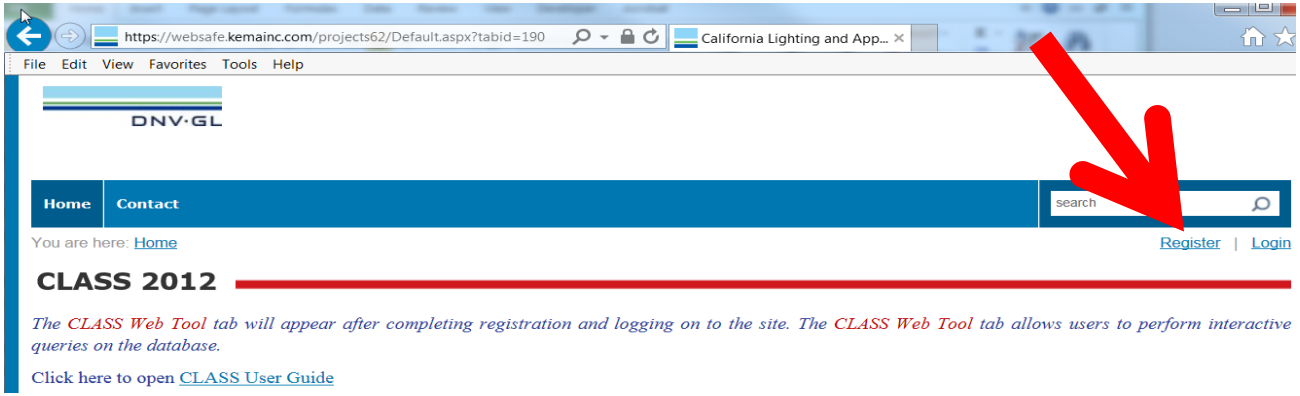
2012 California Lighting and Appliance Saturation Study (CLASS)

What's Included?

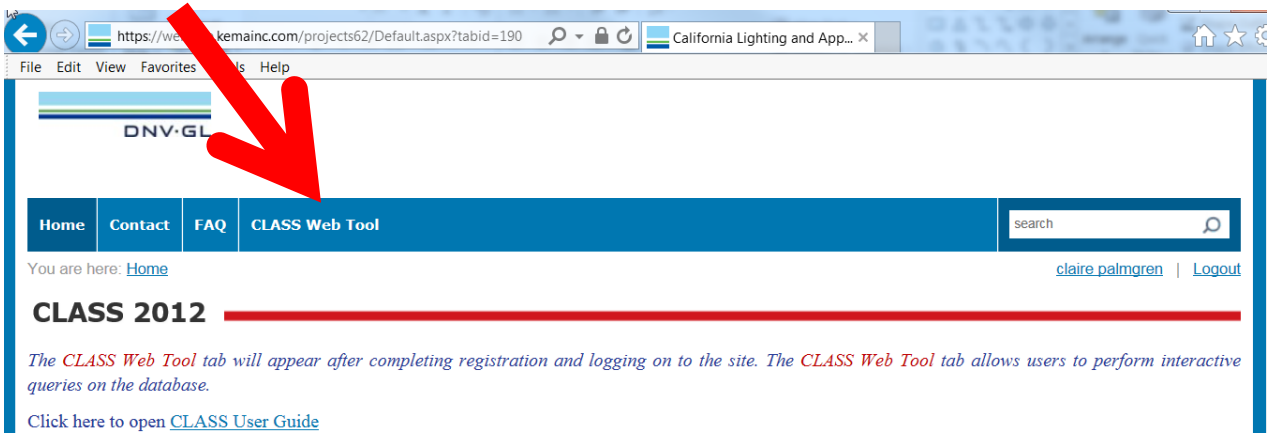
- CLASS site visits included full inventory of installed lighting characteristics and lamps in storage.
  - Provided update to saturation and efficiency characteristics from CLASS studies conducted in 2000 and 2005
  - To facilitate understanding of future energy savings potential and past accomplishments in the residential sector
- Visited 1,987 households in PG&E, SCE and SDG&E electric service territories
  - Included single-family, multi-family and mobile homes with individually-metered electric accounts
- Collected lighting characteristics within all areas of homes
  - Fixtures (quantity, type, control type)
  - Lamps (quantity, base type, shape, technology, wattage)
  - Location (home area type, i.e. indoor/outdoor, area category)

How to Access the Data

- Visit https://websafe.kemainc.com/projects62/Default.aspx?tabid=190
- Register to obtain access to the CLASS Web Tool ("cwt" will be added as suffix to username)



- After logging in, click on "CLASS Web Tool"



Demo

- Accessing the site
- Querying data
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Questions?

Jenna Canseco
jennifer.canseco@dnvgl.com
510-891-0446 x44121

www.dnvgl.com

SAFER, SMARTER, GREENER

CSS/CMST WEBSITE

Priya Sathe

October 20, 2015

AGENDA

- Overview of 2010-12 CPUC CSS/CMST Study
- Overview of the Lighting Analysis
- Overview of Data Gathered
  - Commercial Saturation Survey
  - Commercial Market Share Tracking
- The CSS/CMST Website

OVERVIEW

The 2010-12 CSS/CMST effort resulted in three reports summarizing research findings.

- Commercial Saturation and Commercial Market Share Tracking Study Telephone Survey Findings
- Commercial Market Share Tracking Study (CMST)
- The Commercial Saturation Survey (CSS)

COMMERCIAL SATURATION SURVEY (CSS)

- On-site Surveys of non-residential customers in the CA IOU Service Territories
  - On-Site Surveys – 1,439 (used in final analysis)
- Measures Currently Installed in Commercial Buildings
  - Food/Liquor, Health Medical (excluding Hospitals), Offices, Restaurant, Retail, Schools, Warehouse, Misc.
  - Whole Building Energy Intensity (EI)
  - Saturation of Measures by Type and Efficiency
    - Lighting, Small HVAC, Refrigeration, TVs, Office Equipment, EMS.
  - Presence of DG Equipment, Occurrence of HVAC Maintenance, etc.

COMMERCIAL MARKET SHARE TRACKING (CMST)

- Newly installed measures (2009-2012) in non-residential buildings
  - Linear Fluorescents, TVs, and Small Packaged HVAC
- Phone and on-site surveys of non-residential customers in the CA Electric IOU service territories

CSS/CMST DATA

CSS Lighting

- Lighting was classified as Linear Fluorescent, CFL, LED, Halogen, Incandescent, HID, or other
- Indoor and outdoor lighting
- Advertising lighting and exit signs
- Lighting controls
- Lighting that is burnt out, inoperable, or in storage
- Information on watts and lumens
- Make and model lookups for Linear technologies
- Estimates of lighting usage
- Comparisons to CEUS
- Produced Results by Efficiency Level by IOU, Business Type, Customer Size, and Participant Flag (2010-12 EE).

CMST Lighting

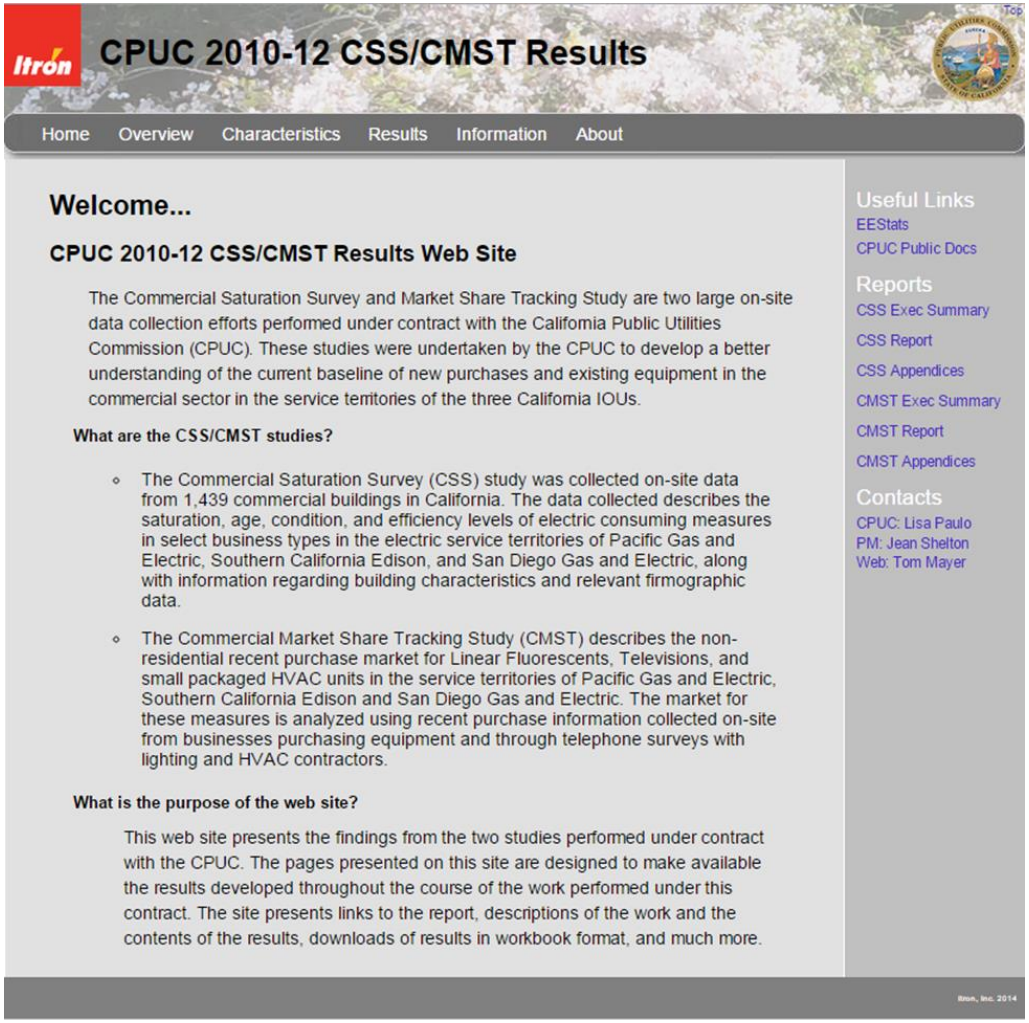
- Collect information from businesses on recently purchased Linear Fluorescents
- Produced market shares of recent purchase efficiency levels by IOU, Customer Size, and Program Participant (2009-12 EE) based on onsite survey findings.
- Produce estimate of the quantity of technologies purchased from 2009-2012
- On-site surveys with non-residential customers who have purchased a high-priority measure from 2009 to 2012
  - 772 on-site surveys
    - 568 on-site surveys with customers installing Linear Technologies

CSS/CMST WEB SITE

http://capabilities.itron.com/wo024/

CPUC 2010-12 CSS/CMST RESULTS WEB SITE

http://capabilities.itron.com/wo024/



THE CSS/CMST WEB SITE LIVE

- Let’s bring the site up and click through some of the tabs to see how it works.

THANK YOU

Itron

www.itron.com

Lighting Technology Overview

Lighting Technology Overview

Understanding the Updates

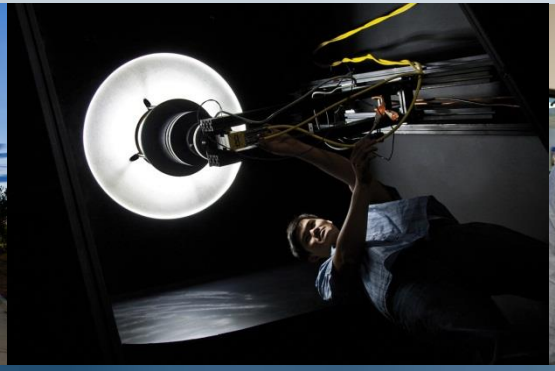
Nicole Graeber, Senior Development Engineer
negraeber@ucdavis.edu
California Lighting Technology Center
University of California, Davis

Mission

To accelerate the development, deployment and commercialization of energy-efficient lighting and daylighting technologies in partnership with utilities, manufacturers, end users, builders, designers, researchers, academics, and governmental agencies.

MISSION-DRIVEN ACTIVITIES:

- Research & Development
- Demonstration & Outreach
- Education & Training

FOUNDING ORGANIZATIONS

UTILITIES

MANUFACTURERS

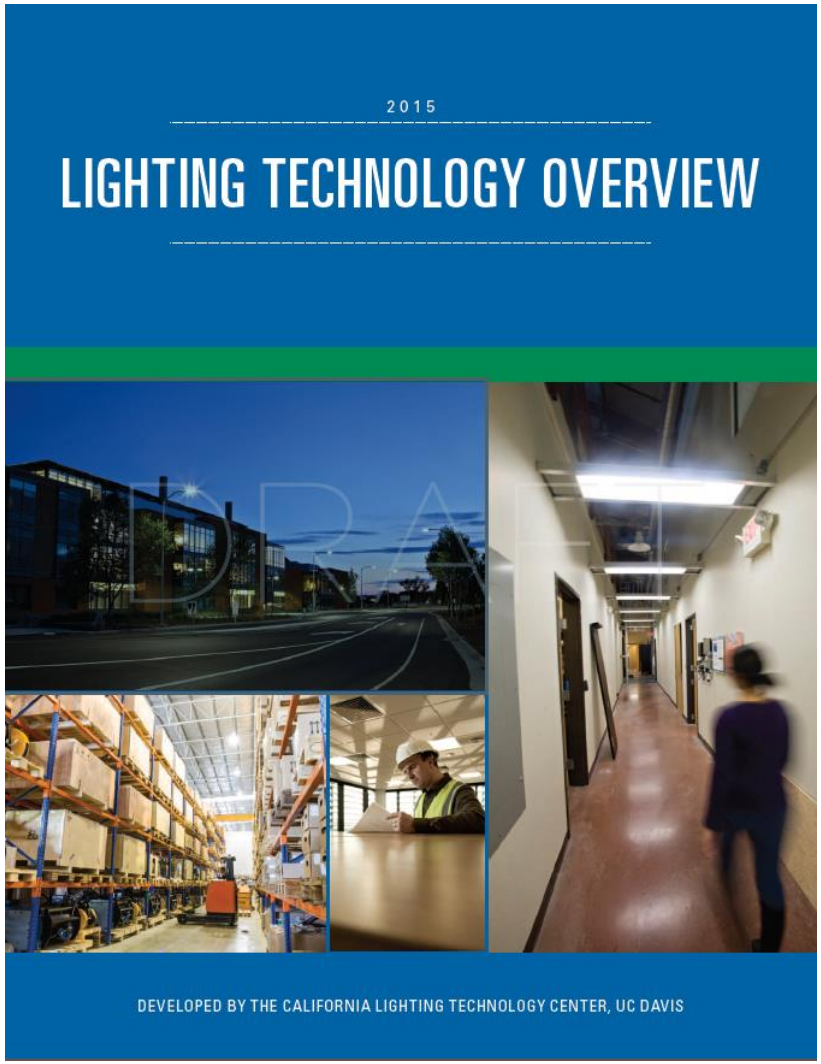
LARGE END-USERS

CALIFORNIA'S STRATEGIC LIGHTING ACTION PLAN

Baseline standards for a 60–80% statewide reduction from a 2010 baseline in electrical lighting energy use by 2020.

Lighting Technology Overview Timeline

Table of Contents



LED LAMPS & LUMINAIRES

Introduction to LEDs

- **History of LEDs**
  - First practical application of LEDs (1962)
  - LEDs used as general illumination in building applications (early 2000s)
- **LED Technology: How it Works**
  - Solid-State Electroluminescence
- **Current LED Specifications**
  - Efficacy: ~170 lumens per Watt
  - Life: 25,000 to 100,000 hours
  - CCT: 2,500 K to 5,000 K
  - CRI: 80 to 97

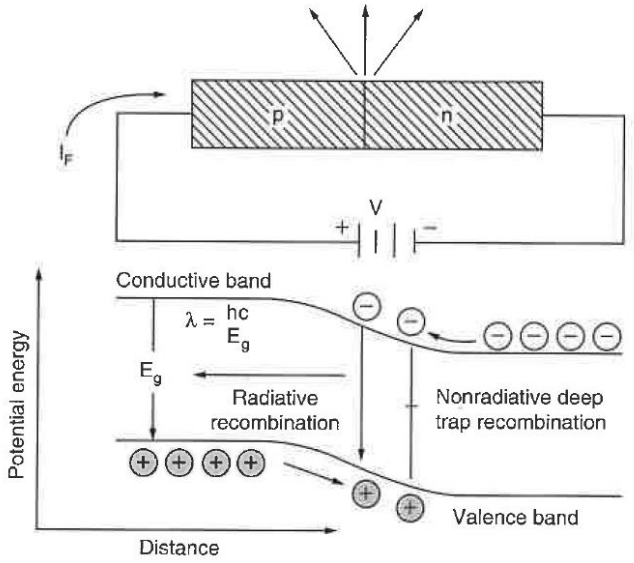
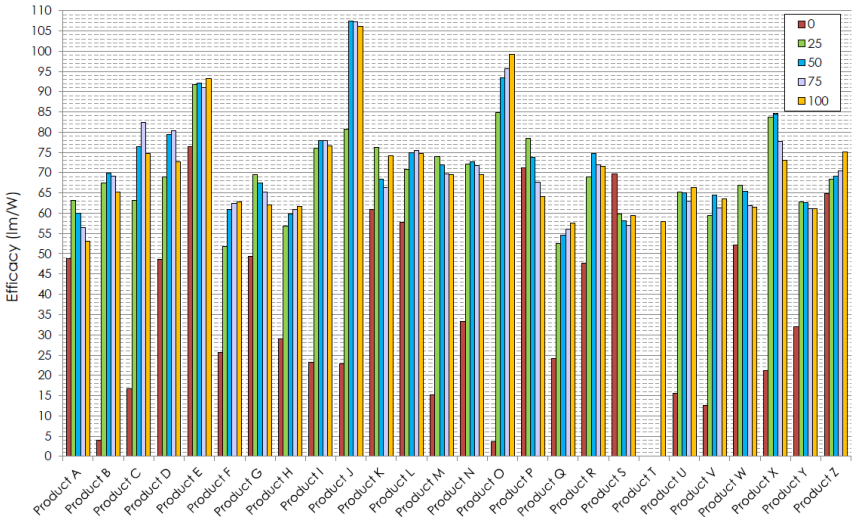
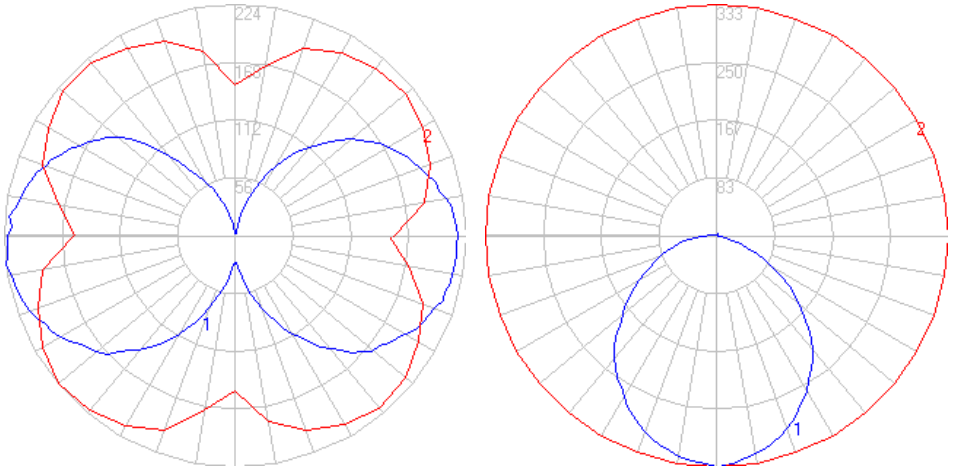


Photo Credit: IES Lighting Handbook, 9th Edition

Factors to Consider

- Vintage LED Light Engine or Modules
- Heat Management
- Optics and Housing Materials
- Light Output and Distribution
- Dimming





INTERIOR LED LAMPS & LUMINAIRES

Interior LED Product Types

Omnidirectional (A19) Lamps

Recessed Downlights

Directional Lamps

Troffers & Surface Mounts

Tubular LEDs

High-Bay & Low-Bay Lighting

Track Lighting

Parking Garage Luminaires

What is included in each section?

- **Expected Energy Savings:** This section outlines the opportunities for energy-use reduction considering the current market for this technology.

- **Factors to Consider when Comparing Products:** When selecting products, it is important to consider the most recent market surveys, publically available test reports and off-the-shelf availability for any retrofit project or program.

- **Example Products:** Commercially available products

- **Case Studies:** Case studies provide information about technology installations with verifiable energy savings.

Omnidirectional (A19) Lamps

- Product introduction
- Expected energy savings
- Factors to consider when comparing products
- Callout directing readers to additional resources

Omnidirectional (A19) Lamps

A variety of LED A19 alternatives are now available to replace traditional products. For example, the DesignLights Consortium (DLC) Qualified Products List includes multiple LED A19 lamps ranging from 6 to 23W with a luminous efficacy range of 52 to 100lm/W.[5] LED A19 availability has significantly increased since 2010, according to the U.S. Department of Energy (DOE)'s CALiPER (Commercially Available LED Product Evaluation and Reporting) program.[6] Results from the CALiPER program show that the cost per lumen of A19 LED lamps dropped by 50% between August 2010 and November 2011. In addition, LED replacement lamps have longer lifetimes than incandescent and compact fluorescents lamps (CFLs), with rated lifetimes ranging from 10,000 hours to 50,000 hours.

Information on LED A19 performance is available from a variety of sources. For example, CLTC hosts an online product database that provides access to LED replacement lamp performance data for statistical analysis and comparative evaluation. The database is accessible through a web-based interface (**ledperformancedatabase.org**). It includes data from multiple sources, including CLTC test labs, other research programs, certified laboratories and lighting manufacturers.

EXPECTED ENERGY SAVINGS

The California residential lighting market is still largely untransformed with respect to this product category. A 2012 survey of California IOU residential customers determined there were 22 incandescent lamps used per household on average. With more than 12.5 million California households as of 2013, traditional incandescent lighting consumed nearly 10,000 gigawatt-hours (GWh) of electricity each year.[7]

LED A19 lamps also offer opportunities for energy use reductions in many non-residential applications. Restaurant and retail applications typically include track lighting, chandeliers, pendants and wall sconces, which often utilize incandescent lamps. The hospitality market also represents a significant opportunity. For example, in the Southern California Edison (SCE) service territory, there are approximately 110,000 hotel rooms and many use portable desk lamps or torchieres with A19 lamps.[9] The long lifetimes for LEDs make the switch from incandescent or CFL to LED attractive to these business operators.

With the exception of the retail sector, less than 5% of commercial pin and medium screw base lamps utilized LED technology, according to the California Commercial Saturation Survey (CSS) published in 2014.[8] In the retail sector, 13% of these lamps used LED sources, according to the same study.

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

As a result of the rapid growth in the commercial LED market, it is important to consider the most recent market surveys, publically available test reports and off-the-shelf availability for any retrofit project or program. Note, market surveys do not represent all products currently available and should be viewed as a snapshot of the overall LED market at the time of the survey's publication. To better understand product performance, third-party testing, funded by agencies such as DOE, California Energy Commission and California IOUs, should be consulted to verify manufacturer claims of equivalency to the traditional light sources they are marketed to replace. Consumers should consider verified product performance as opposed to claimed product performance.

For example, **ledperformancedatabase.org** includes 33 products marked as replacements for a traditional 60W incandescent. The average power consumption of these LED replacements is 12W, an 80% savings over incandescent if used at full output.

LED Performance Database
ledperformancedatabase.org
The LED Performance Database houses all raw and derived data obtained from comprehensive testing of a representative sample of commercially available LED replacement lamps.

- Supplemental charts to support energy savings opportunities of highlighted technology

Additional savings can be achieved if the LED lamp is paired with a dimmer. However, to deliver suitable performance, it is important that the lamp and dimmer be compatible. Compatibility information is typically included with product packaging. Additional LED lamp and and controls testing results are available from groups such as Pacific Gas and Electric Company (PG&E), CLTC and Pacific Northwest National Lab.[10]

In California, it is also important to consider LED lamp performance with respect to state building and appliance standards. Applicable LED replacement lamp performance standards include ENERGY STAR®,[11] Title 24,[12] California Appliance Efficiency Regulations (Title 20),[13] and the Voluntary California Quality LED Lamp Specification (CQS).[14] The CQS is a statewide quality standard for LED replacement lamps that exceeds ENERGY STAR® qualifications. Many California utilities only incentivize LED replacement lamps that meet the CQS requirements. A summary of the current ENERGY STAR® and CQS specifications are provided in Table 1. A full comparison may be found at **ledperformancedatabase.org/pages/standards**.

Table 1. Specification Comparison

Metric	Energy Star®	Voluntary California LED Lamp Specifications
Correlated Color Temperature (CCT)	2,700 K, 3,000 K, 3,500 K, 4,000/4,100 K, 5,000 K, 6,500 K*	2,700 K, 3,000 K**
Efficacy for Omnidirectional Lamps: <15 / >15 Watts (lumens / Watt)	55/65	N/A
Efficacy for Omnidirectional Lamps: <20 / >20 Watts (lumens / Watt)	40/50	N/A
Luminous Intensity Distributions (Omnidirectional)	Lamp shall vary by no more than 25% from average of all measured values (no less than 5% total flux shall be emitted in 135°–180° zone)	Per Energy Star V. 1 Draft 2
Color Rendering Index (CRI)	(Ra) ≥80; R9 > 0	(Ra) ≥90; R9 > 50
Rated Life (Years)	Decorative lamps ≥ 15,000 hours; All other lamps ≥ 25,000 hours, All lamps operational at 3,000 hours, 90% operational at 6,000 hours	Per Energy Star requirements
Flicker	Lamp average light output periodic frequency, highest percent flicker, and highest flicker index shall be reported	Lamps shall be free of flicker over full range of operation from 10%-100% light output
Warranty	< 15,000 lamp life, 2 year minimum warranty; ≥ 15,000 lamp life, 3 year minimum warranty	Minimum 5 year warranty

* Within 7-step MacAdam Ellipse from designated CCT
** Within 4-step MacAdam Ellipse from designated CCT

- Example products of commercially available technologies
- Case studies illustrating existing sites that incorporate this technology
  - Verified energy and cost savings

EXAMPLE PRODUCTS

Cree TW A19
cree.com/Lighting/Products/Indoor/Consumer/Standard-AType-Bulbs

- 800 lumens with 13.5 W power usage
- 59 lm/W efficacy
- 93 CRI and CCT of 2,700 K
- Dimmable
- 25,000 hour rated life

Feit A19
feit.com/led-lamps/Enhance_LED_A-Bulbs

- 820 lumens with 13.5 W power usage
- 60 lm/W efficacy
- 93 CRI and CCT of 2,700 K
- Dimmable
- 25,000 hour rated life

GreenCreative A19
gc-lighting.com/products/a19-9w-dim/

- 800 lumens with 9 W power usage
- 89 lm/W efficacy
- 92 CRI and CCT of 2,700 K
- Dimmable
- 25,000 hour rated life

CASE STUDIES

Restaurant Lighting Retrofit, Sunnyvale, CA
▸ ecoact.org

Under PG&E's Silicon Valley Energy Watch program, Ecology Action retrofitted the lighting in a large sit-down restaurant. One hundred nine 60 W incandescent lamps illuminated the main dining hall. They were replaced one-for-one with 11 W Philips LED A-lamps, saving 49 W per lamp. The project achieved 27,345 kilowatt-hours (kWh) and 5.04 kilowatts (kW) of total savings.

Fry's Electronics Store, San Jose, CA
▸ etcc-ca.com/sites/default/files/reports/ET12PGE1481%20Retail%20LED%20updated%2003132014.pdf

At a Fry's Electronics store, Philips Endura A19 lamps replaced the 60 W incandescent lamps and 19 W CFLs in 27 checkout chandeliers. Replacing the 135 lamps with LEDs saved 3,274 kWh or about $458 in annual energy costs.

Mirage Hotel and Casino, Las Vegas, NV
▸ usa.lighting.philips.com/projects/mirage.wpd

The Mirage Hotel and Casino's convention complex, The Mirage Events Center, replaced 4,000 incandescent lamps used in sconces and chandeliers with Philips EnduraLED A19 lamps. The new lamps consumed only 7 W, providing energy cost savings of about $60,000 per year compared to the 18 W and 42 W incandescents. The longer LED lamp life helped the facility meet its goals to reduce maintenance costs and re-lamping in busy areas.

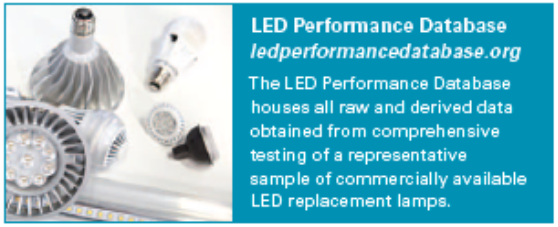
Omnidirectional (A19) Lamps

Expected Energy Savings

- California market share
  - Residential incandescent lamp electricity consumption: ~10,000 GWh/year
  - Commercial (sans retail) LED deployment: <5%
  - Retail sector LED deployment: 13%

Factors to Consider when Comparing Products

- Recent market surveys (snapshots)
- Publically funded third-party testing resources
  - Average power consumption of omnidirectional LEDs:
    - 12 Watts → 80% savings over 60 Watt incandescent



Omnidirectional (A19) Lamps

Example Products

Cree TW A19

cree.com/Lighting/Products/Indoor/Consumer/Standard-AType-Bulbs

- 800 lumens with 13.5W power usage
- 59lm/W efficacy
- 93 CRI and CCT of 2,700K
- Dimmable
- 25,000 hour rated life

Feit A19

feit.com/led-lamps/Enhance_LED_A-Bulbs

- 820 lumens with 13.5W power usage
- 60lm/W efficacy
- 93 CRI and CCT of 2,700K
- Dimmable
- 25,000 hour rated life

GreenCreative A19

gc-lighting.com/products/a19-9w-dim/

- 800 lumens with 9W power usage
- 89lm/W efficacy
- 92 CRI and CCT of 2,700K
- Dimmable
- 25,000 hour rated life

Omnidirectional (A19) Lamps

Case Studies

Restaurant Lighting Retrofit, Sunnyvale, CA

- ecoact.org

Under PG&E's Silicon Valley Energy Watch program, Ecology Action retrofitted the lighting in a large sit-down restaurant. One hundred nine 60 W incandescent lamps illuminated the main dining hall. They were replaced one-for-one with 11 W Philips LED A-lamps, saving 49 W per lamp. The project achieved 27,345 kilowatt-hours (kWh) and 5.04 kilowatts (kW) of total savings.

Fry's Electronics Store, San Jose, CA

- etcc-ca.com/sites/default/files/reports/ET12PGE1481%20Retail%20LED%20updated%2003132014.pdf

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Directional Lamps

Directional lamps use internal reflectors to provide various light distribution patterns. Products range from narrow-beam-angle spotlights to wide-beam-angle floodlights. As of 2010, approximately 94% of all installed directional/reflector lamps in the U.S. used incandescent or halogen sources.[15] Many directional lamps can be replaced with LED equivalents. Some of the most common are:

- **Parabolic aluminized reflector (PAR) lamps:** Often used in downlights and track lighting, PAR lamps have a wider bulb diameter than A19 lamps. Incandescent PAR lamps consume 65 to 80 W on average,[16] with an efficacy of 5 to 15 lm/W.[17] LED products have higher efficacies, from 42 to 100 lm/W,[18] and thus are available in lower wattages, 5 to 23 W.
- **Bulged reflector (BR) lamps:** BR lamps are similar to PAR lamps, with the distinction that the top of the lamp is convex with respect to the lamp base. PAR lamps have a flat form factor. Incandescent BR lamps range in wattage from 65 to 80 W,[19] have an efficacy of 5 to 15 lm/W.[20] LED BR replacement lamps have efficacies of 54 to 97 lm/W and wattages of 7 to 22 W.[21]
- **Multifaceted reflector (MR) lamps:** MR lamps are pin-based and available in a variety of sizes, including MR16 and MR11. Halogen MR lamps, the most common source for this lamp size, range in power between 20 and 100 W,[22] and an efficacy of 8 to 20 lm/W.[23] LED MR lamps range in efficacy from 30 to 84 lm/W and from 2 to 12 W.[24]

EXPECTED ENERGY SAVINGS

The potential energy savings for directional LED lamp replacements varies depending on the legacy source being replaced. Replacing incandescent or halogen directional lamps with LED alternatives can produce energy savings between 50 to 90%.[25, 26, 27, 28, 29, 30]

According to DOE, approximately 80% of reflector lamps in use in United States residential applications were incandescent or halogen light sources as of 2010.[31] This same lamp type consumed a total of 16% of total residential energy usage.[32] In interior residential applications, which compose 14,230 GWh of California's annual energy use, switching to LED sources offer potential statewide savings of 509 GWh when replacing pin-base halogen lamps (6% of current interior lighting).[33] For exterior residential lighting in California, replacing halogen flood medium screw-base lighting with LED lamps offers 294 GWh of potential annual energy savings and replacing incandescent flood medium screw-base lighting with LED lamps offers 812 GWh of potential annual energy savings.[34]

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

Light distribution and installation location are primary attributes to consider before product selection and installation. As with any directional lighting application, proper lighting distribution is vital to properly illuminate points of interest. LEDs are highly directional sources. Directional LED lamps can often achieve better focused and higher illumination on intended targets compared to traditional sources. Consumers should consider the amount of light reaching their intended target and not just the total light produced by the lamp. At first glance, a traditional source may appear to deliver more light, but a closer investigation may reveal that the LED product delivers more light where it's actually needed. Such considerations may allow selection of a product with much lower energy consumption and equivalent or better light output at the point of interest.

A second consideration is the installation location and ventilation. LED lamps require good ventilation and thermal management for optimal performance. In directional applications, the fixture may often be recessed in the ceiling or wall. This can limit airflow to the LED lamp. Consumers should compare installation location features such as lamp base orientation and Insulation Contact (IC)-rating of the fixture housing against the operating conditions used to determine the performance characteristics listed on LED product packaging. When the two differ, LED products may not deliver the performance claimed.

Some other factors to consider include using product ratings such as Energy Star to help evaluate product performance, the manufacturers' longevity in the marketplace, and warranty information.

Visual flicker can also be an issue for LED lamps. To avoid visible flicker in a LED MR16 system, for example, research shows that LED lamps paired with a driver designed for compatibility with a basic electronic transformer or electronic transformers designed specifically for LED lamps will deliver the least amount of visual flicker. In addition, avoid dimming this product except in conjunction with a manufacturer recommended or reverse-phase dimmer.[35]

EXAMPLE PRODUCTS

OSRAM SYLVANIA ULTRA LED PAR38
sylvania.com/en-us/products/new-products/Pages/ultra-par-family.aspx

- 640 to 1,300 lumens with 10 W to 20 W power usage
- 65 lm/W efficacy
- 95 CRI and CCT of 2,700 K or 3,000 K
- Dimmable to 10%
- Up to 50,000 hour lifetime

Soraa Vivid MR16
soraa.com/products/MR16-GU5.3

- 460 to 480 lumens with 12 W power usage
- 38 to 40 lm/W efficacy
- 95 CRI and CCT of 2,700 K or 3,000 K
- Dimmable to 20%
- 35,000 hour average life

Cree LBR BR30 LED Lamp
cree.com/Lighting/Products/Indoor/Lamps/LBR-Series

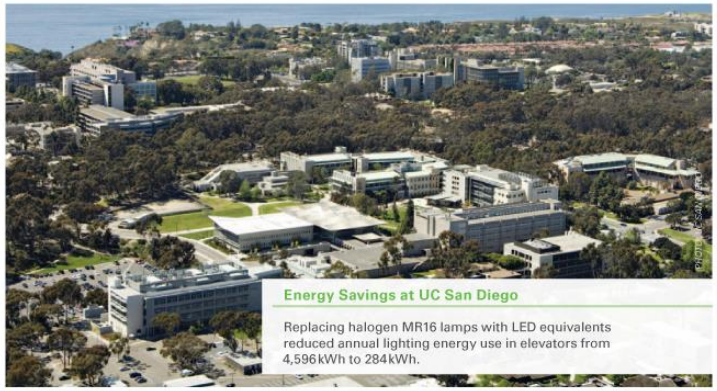
- 600 lumens with 12 W power usage
- 50 lm/W efficacy
- 94 CRI and CCT of 2,700 K
- Dimmable to 20%
- At least 25,000 hour lifetime

PHOTO: PG&E LED PAR38

PG&E Emerging Technologies Program Report: Directional LED Lamps — Laboratory Testing Program

LED replacement lamps have the potential to significantly reduce lighting energy use in the retail sector, where halogen PAR and MR lamps are among the most common choices. The Directional LED Lamps — Laboratory Testing Program was designed to verify manufacturers' product claims about life, lumen maintenance, and color maintenance of directional LED replacement lamps, based on a market cross-section of lamps commonly used in retail applications.

Read the final report at **cltc.ucdavis.edu/publication/directional-led-lamps-laboratory-testing-program**.



Energy Savings at UC San Diego

Replacing halogen MR16 lamps with LED equivalents reduced annual lighting energy use in elevators from 4,596 kWh to 284 kWh.

CASE STUDIES

University of California, San Diego, CA

▸ etcc-ca.com/sites/default/files/reports/Bi-level%20LED%20Elevator%20Cab%20Lighting%20Demo%20Showcase.pdf

The elevator lighting at UC San Diego utilized halogen MR16, fluorescent and CFLs. As part of an LED demonstration project, nine 58.3W halogen MR16 lamps were replaced with nine 3.6W LED lamps. Annual energy use declined from 4,596 kWh to 284 kWh with LEDs, a decrease of 94%.

J. Paul Getty Museum, Malibu, CA

▸ apps1.eere.energy.gov/buildings/publications/pdfs/ssl/getty_museum_gateway_final.pdf

The J. Paul Getty Museum installed an exhibit featuring photographic prints using albumen, which is egg white. A major concern during this installation was the photographs' sensitivity to ultraviolet/infrared radiation. In an effort to minimize damage from light, the museum staff retrofitted 60W PAR38 halogen lamps with 34 Cree 12W PAR38 LED lamps. The annual energy savings was 4,490 kWh. The first year energy consumption cost savings was $539.

Directional Lamps

Expected Energy Savings

- Incandescent/Halogen Directional Lamps
  - → 80% of installed directional lamps
  - → 16% of residential energy use
  - → **LED: 50-90% Savings**

Factors to Consider when Comparing Products

- Light Distribution
  - → Target Illuminance/Design Criteria
- Installation Locations
  - → Thermal management

Directional Lamps

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Tubular LEDs

Tubular LED lamps (TLEDs) are available to replace common linear fluorescent light sources such as 2-foot and 4-ft T8 lamps. TLEDs utilize an array of LEDs distributed along the length of the lamp tube to deliver light from the same form factor as a linear fluorescent lamp. TLEDs are often marketed as a one-to-one replacement for fluorescent lamps, but a large majority of tubular LED replacement lamps require a different electrical system.

New electrical components and rewiring are often necessary to make the existing fixture compatible with the new lamps. Based on the particular LED replacement lamp being considered, a TLED retrofit will typically require changing the electrical wiring, replacing the ballast with an LED driver, or altering the existing lamp holders (or "tombstones") to accommodate the new lamp.

"Drop-in" tubular LED replacement lamps incorporate a driver into the lamp. This allows the tubular LED to utilize existing fluorescent ballasts with no additional rewiring required. With these products, the tubular LED bi-pins connect directly to the existing G13 lamp holders. The thermal performance of the technology must be evaluated while installed in situ to ensure lamp life will not be compromised with the driver components exposed to higher temperatures.

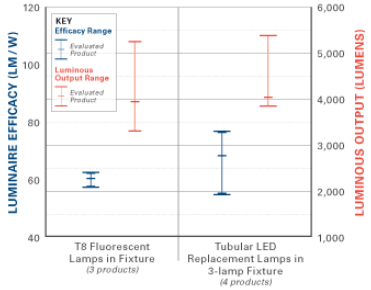
The majority of LED replacement lamps with internal or integrated drivers require line voltage be supplied directly to the lamp holders, bypassing the fluorescent ballast. Internal driver LED lamps may be either single- or double-ended, with power running to one or both ends. LED replacement lamps with external or remote drivers differ still, and require their driver be connected to either the existing tombstone, or directly to the lamp, while using the tombstone merely for stability.

TLED replacements that do not require wiring alterations may be considered a repair and do not trigger the Title 24 code compliance process. An existing linear fluorescent luminaire with TLED lamps is not recognized as an LED lighting system for compliance purposes.

EXPECTED ENERGY SAVINGS

Assuming any system compatibility issues are addressed, TLED retrofits can deliver significant energy savings compared to linear fluorescent lamps. Linear lamps account for 83% of installed commercial lamps in the state, according to the CSS report. The top three market sectors using linears are commercial offices (30%), schools (16%) and retail establishments (14%). Less than 0.5%o of installed linears utilize LED technology.[36] Across most of the commercial sector, existing fluorescent lamps are primarily standard performing products (700–800 series T8 lamps with approximately 80 to 90 lm/W or T12 technology), according the same report. Equivalent TLEDs are available, which are 10 to 50% more efficacious. A recent search of the Lighting Facts website revealed three products with lamp efficacy greater than 140 lm/W and light output equivalent to a standard T8 lamp.[37] For indoor commercial lighting, which accounts for approximately 26,000 GWh annually according to a 2014 Energy Commission study,[38] conversion of linear fluorescent technology to LED can save at least 2,600 GWh each year, assuming just a 10% improvement in efficacy between incumbent technology and TLED replacements. Savings could be much greater and are contingent on the specific product installed.

Figure 1. Luminaire efficacy and luminous output by product category



CALiPER Exploratory Study: Recessed Troffer Lighting, Prepared for DOE by the Pacific Northwest National Laboratory, 2013.

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

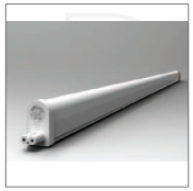
Replacing existing linear fluorescent lamps with TLEDs requires minimal new hardware, but this strategy also presents some unique challenges that should be understood thoroughly before purchase or installation.

The electrical incompatibilities between linear fluorescent and linear LED lamps constitute the most important safety issue facing tubular LED technology. Proper documentation and labeling of TLEDs is crucial to avoid electric hazards and protect the safety of maintenance staff and end users after the retrofit.

Another electrical wiring point of interest is whether the lamp holder is shunted for instant start fluorescent ballasts or un-shunted for rapid start ballasts. Generally, TLEDs that receive electricity through the lamp holder require un-shunted lamp-holders to operate as intended by the manufacturer.

Light distribution patterns may change when replacing fluorescents with a TLED product. TLEDs incorporate multiple, directional light sources into a linear form factor through varied optical design strategies. As a result, tubular LED and linear fluorescent lamps installed in the same troffer can produce different light distribution patterns. With some products, initial illumination levels may not be equivalent to fluorescent predecessors so spaces are often overlit compared to recommended values. Consumers should consider how much light is recommended for the application and then match that with appropriate TLED replacements.

EXAMPLE PRODUCTS



GE Lighting Solutions Batten LED

catalog.gelighting.com/apac/luminaire/led-indoor/led-fixture/f=t8-batten/d=0/?l=en&r=apac

- 2,840 lumens with 32W power usage
- Up to 88.75lm/W at source level
- 83 CRI and color temperature of 4,000K
- Dimmable
- 30,000 hour rated life

Delviro Energy ZEN Linear

delviroledlighting.ca/project/zen-linear-led-fixture/

- 2,484 to 6,900 lumens with 20 to 60W power usage
- Up to 130lm/W at source level
- 84 CRI and color temperature of 3,000K to 5,000K
- 40,000 hour rated life
- 0 to 10V dimming
- 200,000 hour rated life

Cree UR Series

cree.com/Lighting/Products/Indoor/Upgrade-Solutions/UR-Series

- 3,600 or 4,500 lumens with 36 or 44W power usage
- Up to 102lm/W at source level
- 80 CRI and color temperature of 3,500K or 4,000K
- Dimmable, step level to 50% or 0 to 10V dimming to 5%
- 50,000 hour rated life

CASE STUDIES

Parking Garages, Louisville, KY

▸ energyfocusinc.com/?s=louisville+parking

The City of Louisville wanted to reduce the annual energy costs for its 12 parking garages, increase overall safety, and reduce maintenance. Energy Focus Vapor Tight Series LED housings with TLEDs were chosen to replace 2,260 high-pressure sodium 150W canopy lights and 1,420 fluorescent 175W canopy lights. The retrofit achieved a 145W reduction per fixture for a total annual energy savings of $410,239. Outfitting the fixtures with motion control occupancy sensors increased the energy savings since lighting was utilized only when needed and there was no wasted light when the garage was empty.

Scappoose City Hall, Scappoose, OR

▸ bpa.gov/EE/Sectors/Commercial/Documents/scappoose_cityhall_casestudy.pdf

The Scappoose City Hall wanted a more energy-efficient solution for the facility, which housed spaces including a courtroom, administration offices, and the police station. About 300 existing T12 lamps (40W each) were replaced with new TLEDs (18W each) from Creative Lighting Solutions, Inc. Occupants feel the facility is now much brighter and the expected energy savings from the project is 61%.

Penn Manor Middle School, Lancaster, PA

▸ energyfocusinc.com/lighting-resources/case-studies/municipal-university-schools-hospitals/penn-manor-school-district/

Penn Manor Middle School replaced fluorescent fixtures with Energy Focus Series 100 lamps. With more than 3,700 TLED lamps installed, the school improved its classroom lighting , reduced its lighting maintenance needs, and reduced lighting energy consumption by 50%, or $32,122 per year.

PHOTO: CLTC, UC DAVIS

Significant Energy Savings

Assuming safety and performance considerations are addressed, TLEDs can deliver significant energy savings compared to existing linear fluorescent lamps.

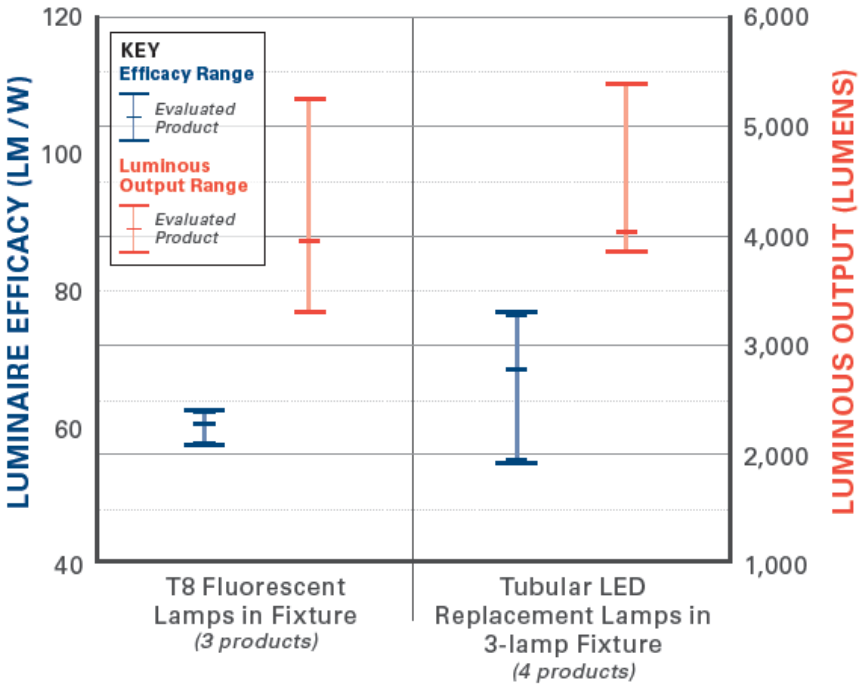
Tubular LEDs

Expected Energy Savings

- Linear lamps are 83% of installed commercial lamps
- Less than 0.5% of market have been converted to LED
- LEDs are 10 - 50% more efficacious than fluorescent T8 lamps

Factors to Consider when Comparing Products

- Electrical Compatibility
  - Safety Documentation
- Light Distribution
  - Design Criteria



CALiPER Exploratory Study: Recessed Troffer Lighting, Prepared for DOE by the Pacific Northwest National Laboratory, 2013.

Tubular LEDs

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Significant Energy Savings

Assuming safety and performance considerations are addressed, TLEDs can deliver significant energy savings compared to existing linear fluorescent lamps.

Track Lighting

Track lighting is typically used in general retail spaces, restaurants, galleries, museums and some residential spaces. For sensitive applications, LEDs can reduce damage to organic materials and historic artifacts caused by ultraviolet radiation, which is more prevalent with incandescent and halogen sources. In all applications, LED systems require less maintenance, which translates directly to cost savings.

Traditional track lighting typically uses incandescent or halogen pin or screw-base lamps (with and without reflectors) in combination with track heads and an energized track. LED retrofit options for track lighting include LED lamp replacements and a full retrofit of track heads with dedicated LED units. Dedicated LED track heads that fully replace the existing track head are designed with components (drivers, diode arrays, housings, heat sinks, and optics) built to function together as a unit. Dedicated LED track heads can often be installed on the same track used by traditional pin and screw-base lamps. LED track heads are available from a variety of manufacturers to replace existing systems.

EXPECTED ENERGY SAVINGS

Lamps used in track lighting are predominantly incandescent, halogen or metal halide (MH), so switching to LEDs can reap deep energy savings. Four studies looking at replacements of halogen lamps with LEDs or existing halogen systems with new LED track systems produced energy savings from 60 to 80%.[39, 40, 41, 42] PG&E estimates that within its service territory, conversion of existing MR16 lamps, which are the most utilized directional light source (for track and other applications) to dedicated LED units could save 77%, with associated annual savings of approximately 420 GWh. Most dedicated LED track heads range in efficacy between 40 to 90 lm/W[43] and savings estimates are similar to those stated in the directional lamp section. The total amount of installed track and associated energy use of lamps installed in this specific mounting type is unknown.

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

With LED lamp replacements, consumers should consider coupling the retrofit with current limiting devices for the track. In this way, the retrofit will deliver persistent savings, that otherwise could be negated if additional track heads and/or non-LED sources can be added back to the system. When combined with a current limiting device, the track itself cannot deliver enough current to allow for a significant increase in the number or wattage of lamps used. As with any one-to-one LED lamp replacement, consumers should understand performance with respect to thermal management, current regulation, and controls compatibility.

Consumers should consider component compatibility prior to product selection. Dedicated LED track heads are rated for use only with specific models of track. Dimmable, dedicated LED track heads are expensive, but non-dimmable units are available for less than $100 each.

EXAMPLE PRODUCTS

Juno Conix II LED Trac Lighting
junolightinggroup.com/search-results.aspx?Search=conix%20II

- 1,000 to 4,300 lumens with 19W to 64W power usage
- 53 to 67 lm/W efficacy
- 90 CRI and CCT of 2,700K, 3,000K, 3,500K or 4,000K
- Dimmable
- 50,000 hour rated life

ERCO Light Board Spotlight
erco.com/products/indoor/swf-3circuit/spotlights-floodlights-and-wallwashers-14/en/

- 1,140 lumens with 12W power usage
- 95 lm/W efficacy
- 90 CRI and CCT of 3,000K
- Dimmable
- 50,000 hour rated life

Bruck Chroma Magnum II Track Spot
brucklighting.com/products/lights/chroma

- 1,000 lumens with 12.7W power usage
- 79 lm/W efficacy
- 80 to 95 CRI and CCT of 2,700K, 3,000K, 3,500K or 4,000K
- Dimmable
- 50,000 hour rated life

CASE STUDIES

Safeway, San Francisco Bay Area, CA
▸ etcc-ca.com/sites/default/files/reports/ET12PGE3351_12_28_2012.pdf

A Safeway retrofitted low-voltage halogen track lighting with LED luminaires. Sixty-two 50W halogen MR16 lamps and fixtures were replaced with 45 15W Amerlux Hornet integrated LEDs. On a storewide basis, the retrofit produced a 77% reduction in peak demand, energy usage and costs. The LED longevity and the elimination of halogen relamping could provide a projected maintenance savings of 35%.

San Diego Zoo, San Diego, CA
▸ etcc-ca.com/sites/default/files/reports/San%20Diego%20Zoo%20Gift%20Shop%20LED%20Lighting.pdf

The San Diego Zoo replaced existing halogen track lighting in the zoo gift shop with LED alternatives. Two hundred fifty-four 54.5W halogen MR16 lamps were replaced with 11W LED PAR20 lamps and track heads, producing energy savings of 80%. The annual energy cost savings was $10,163.

Nordstrom Stores Lighting Retrofit
▸ bpa.gov/EE/Sectors/Commercial/Documents/Nordstrom_casestudy.pdf

Spotlights using 50W incandescent halogen were the standard for Nordstrom stores. Two years into a three-year project to convert to ceramic metal halide (CMH), Philips recommended installing LED spotlights to save energy. They also offered a longer lamp life and lower maintenance costs. Nordstrom switched to Lytespan LED track and spotlighting systems at some locations in Oregon and Washington. The installed CMH products would be used and relamped until they reached the payback period. The energy savings from the LED retrofit was 15 to 20%. Nordstrom planned to move forward with LED retrofits for the spotlights in other stores.

Track Lighting

Expected Energy Savings

- Incumbent technologies: Incandescent, halogen, metal halide

  → **LED: 60 - 80% Savings**

Factors to Consider when Comparing Products

- Track component compatibility (track, head, lamp)
- Add current limiting devices to deliver persistent savings
- Thermal management
- Controls compatibility

Track Lighting

Example Products

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- 53 to 67 lm/W efficacy
- 90 CRI and CCT of 2,700K, 3,000K, 3,500K or 4,000K
- Dimmable
- 50,000 hour rated life

ERCO Light
Board Spotlight
erco.com/products/indoor/swf-3circuit/spotlights-floodlights-and-wallwashers-14/en/

- 1,140 lumens with 12W power usage
- 95 lm/W efficacy
- 90 CRI and CCT of 3,000K
- Dimmable
- 50,000 hour rated life

Bruck Chroma
Magnum II Track Spot
bruckLighting.com/products/lights/chroma

- 1,000 lumens with 12.7 W power usage
- 79 lm/W efficacy
- 80 to 95 CRI and CCT of 2,700K, 3,000K, 3,500K or 4,000K
- Dimmable
- 50,000 hour rated life

Track Lighting

Case Studies

Safeway, San Francisco Bay Area, CA

▸ etcc-ca.com/sites/default/files/reports/ET12PGE3351_12_28_2012.pdf

A Safeway retrofitted low-voltage halogen track lighting with LED luminaires. Sixty-two 50 W halogen MR16 lamps and fixtures were replaced with 45 15W Amerlux Hornet integrated LEDs. On a storewide basis, the retrofit produced a 77% reduction in peak demand, energy usage and costs. The LED longevity and the elimination of halogen relamping could provide a projected maintenance savings of 35%.

San Diego Zoo, San Diego, CA

▸ etcc-ca.com/sites/default/files/reports/San%20Diego%20Zoo%20Gift%20Shop%20LED%20Lighting.pdf

The San Diego Zoo replaced existing halogen track lighting in the zoo gift shop with LED alternatives. Two hundred fifty-four 54.5 W halogen MR16 lamps were replaced with 11 W LED PAR20 lamps and track heads, producing energy savings of 80%. The annual energy cost savings was $10,163.

Nordstrom Stores Lighting Retrofit

▸ bpa.gov/EE/Sectors/Commercial/Documents/Nordstrom_casestudy.pdf

Spotlights using 50W incandescent halogen were the standard for Nordstrom stores. Two years into a three-year project to convert to ceramic metal halide (CMH), Philips recommended installing LED spotlights to save energy. They also offered a longer lamp life and lower maintenance costs. Nordstrom switched to Lytespan LED track and spotlighting systems at some locations in Oregon and Washington. The installed CMH products would be used and relamped until they reached the payback period. The energy savings from the LED retrofit was 15 to 20%. Nordstrom planned to move forward with LED retrofits for the spotlights in other stores.

Recessed Downlights

Downlights (also commonly referred to as recessed lights or can lights) can be found in both residential and commercial sectors. Downlights may use incandescent, HID, CFL or LED light sources. The luminaire housing typically ranges from 4 to 12 inches in diameter. For certain retrofit situations, an LED module may use the existing screw base as a power source for the lamp and clip into the existing housing. Sometimes a trim kit is added. In other retrofit applications, the existing downlight lamp and housing are fully removed and the retrofit unit is installed in the same location. In new construction applications, LED product installation varies little from traditional downlights.

As one of the first general illumination LED applications, LED downlight technology has matured over the past decade. Best-in-class products, such as winners of the Next Generation Luminaires™ SSL Design Contest, have demonstrated efficacy improvements in this product category of 20 to 30 lm/W, in just five years.[44] LED downlights offer longer lifetimes and reduced maintenance costs compared to existing fluorescent or incandescent sources.

LED downlights are now available for high-ceiling applications (ceiling height of 20 ft or more). This application has previously been overlooked for lighting retrofits since LED products were unable to provide the light output and efficacy of CFL or CMH counterparts. Products, such as the CS Series by Meteor Lighting, can deliver up to 20,000 lm at 110 lm/W.[45]

Photo courtesy of PNNL

EXPECTED ENERGY SAVINGS

Replacing existing incandescent downlights with dedicated LED downlights or retrofit kits delivers energy savings of approximately 80%.[46, 47] Replacing fluorescent downlights with LED options can reduce lighting energy use by 50%.[48, 49] Conversion of existing residential recessed downlights to LED alternatives could save 4,950 GWh annually.[50] In California's commercial sector, where incandescent and CFLs predominate in pin and screw-base applications at approximately 90% or more utilization, savings from conversion to LED alternatives could be significant. Approximately 85% of all California commercial businesses utilize some form of pin or screw-base lamp.[51] Nationwide, total potential savings could be as high as 48,000 GWh, according to a 2008 DOE study.

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

In addition to typical considerations surrounding light output, color and controls compatibility, consumers should consider product serviceability. Downlights that allow for tool-less, below-ceiling maintenance to both the module and driver are preferred over traditional downlight styles, which require maintenance from above, in the ceiling plenum. This feature reduces maintenance costs over the life of the product. In addition, many products are available with "module" systems where a component of the downlight may be exchanged for another when needed instead of replacing the entire unit. This concept may apply to the LED light module, LED driver or system optics. Downlights that allow easy exchange of the LED light module, in particular, are extremely valuable. As LED efficacy improves, consumers may swap an existing LED light module for a higher performing module with little effort or installation cost. System energy-efficiency can continue to improve in line with LED technology.

EXAMPLE PRODUCTS

CREE TW CR6
cree.com/lighting/products/indoor/downlights-us/cr-series

- 575 to 800 lumens with 9.5 to 12.5 W power usage
- 61 to 64 lm/W efficacy
- 90 CRI and CCT of 2,700 K, 3,000 K, 3,500 K or 4,000 K
- Dimmable to 5%
- 50,000 hour rated life

Cooper Lighting Halo ML56 LED Downlighting System
cooperindustries.com/content/public/en/lighting/products/recessed_general_purpose_downlighting.html

- 900 lumens with 13.5 W power usage
- 67 lm/W efficacy
- 90 CRI and CCT of 2,700K, 3,000K, 3,500K or 4,000K
- Dimmable
- 50,000 hour rated life

Amerlux Evoke 2.9" Round Adjustable Gen 2 LED
amerlux.com/products/interior/recessed-downlights

- 555 to 634 lumens with 12 W power usage
- 46 to 53 lm/W efficacy
- 90 CRI and CCT of 3000 K
- Dimmable
- 50,000 hour rated life

CASE STUDIES

Abbey Espresso Bar & Café, Belleville, IL

▸ cooperindustries.com/content/public/en/lighting/resources/LightingStories/The-Abbey-Espresso-Bar-and-Cafe

The Abbey Espresso Bar & Café is more than a coffee shop. It also serves as a live music venue, restaurant, gelato bar, and retail store. The space needed a flexible lighting design that served all these purposes efficiently, effectively and attractively. The dimmable Halo ML56 13.5 W LED recessed downlight from Eaton's Cooper Lighting business provides a warm color temperature and 900 lumens. The project saved more than $2,000 in yearly electricity costs over more traditional 75 W PAR30 lamps.

Southland Christian Church, Lexington, KY

▸ acuitybrands.com/old-solutions/inspire-me/case-studies/southland-christian-church

Southland Christian Church transformed an abandoned mall into a multi-use project with classrooms, open spaces, administrative functions, and a 2,800-seat auditorium. The church needed a fixture that could be both pendant-mounted and recessed since the auditorium had varying ceiling heights that ranged from 12' to 40'. The Gotham Incito downlights accommodated this need and also offered a compact 6-inch aperture. In addition, the facility expects reduced cooling (HVAC) needs due to the lower heat output of the new LED luminaires.

Whole Foods Market, Los Angeles, CA

▸ Contact Chad Clark (chad@regreencorp.com) or Neda Farzan (neda@noralighting.com) for more information

Whole Foods Market partnered with ReGreen to upgrade the lighting in its store in Los Angeles' Fairfax District. The goal was to save energy costs, reduce maintenance, enhance the presentation of products, and improve the visual experience for customers and staff. ReGreen chose the 8-inch Sapphire from NSpec for the project. The retrofit reduced lighting energy consumption by more than 40%, produced annual energy savings of more than $28,000, and cut maintenance costs of more than $5,000 a year.

Recessed Downlights

Expected Energy Savings

- Incandescent → LED: 80% energy savings
- Fluorescent → LED: 50% energy savings

Factors to Consider when Comparing Products

- Light Output
- Color maintenance
- Controls compatibility
- Product serviceability

Example Products

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Troffers & Surface Mounts

Linear fluorescent troffers and surface mount luminaires are ubiquitous to many applications, including commercial offices and classrooms, which in California, account for 30% and 16% of all installed linear fluorescent technology, respectively.[52] Troffers comprise a major part of the lighting in commercial spaces nationwide and represent more than 50% of the luminaires currently in use in the United States.[53]

Implementing LED technology as part of a luminaire retrofit can be done in two ways. One option is installing an LED retrofit kit. These kits have the light source replacement, related electrical components, lenses and in some cases, reflectors in a single package. Since necessary electrical components are included, the kit will work as long as it is the right size for the existing troffer or fixture. Luminaires with atypical dimensions may not support all retrofit kits so test samples with the existing fixture and/or space to ensure compatibility and a successful retrofit.

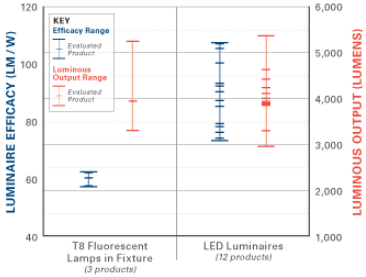
The second option is replacing the existing luminaire with a dedicated LED luminaire. This provides the opportunity to incorporate on-board sensors into the new luminaires if wireless or external controls are not being used. LED luminaires offer a simple electrical installation since the entire luminaire is being replaced. They also typically offer a higher efficacy than lamp replacements or retrofit kits and reduce installation complications. LED fixtures typically have an external driver, which makes it simpler to replace in the event of a failure. A single LED fixture may be offered with a variety of current, color and control options.

In some cases, replacing or modifying a luminaire triggers Title 24 compliance. But, the standards do not specify what technology must be used to fulfill requirements. There is ample opportunity for savings in many commercial applications, regardless of lighting power density (LPD) and controls requirements contained in the current standards. Open office applications offer a significant savings opportunity by pairing high performing LED troffers with occupancy controls. The standards do not have requirements for occupancy-based control of large zones in this application. Programs designed to support increased adoption of LED troffers and surface mounted luminaires, which achieve better than 0.8 watts per square foot (W/ft²) and include occupancy controls is one opportunity for statewide energy savings.

San Diego State University Lighting Retrofit

Energy consumption decreased by 50% in classrooms where LED troffers replaced fluorescent fixtures.

Figure 2. Luminaire efficacy and luminous output by product category



Source: CALiPER Exploratory Study: Recessed Troffer Lighting, Prepared for DOE by the Pacific Northwest National Laboratory, 2013.

EXPECTED ENERGY SAVINGS

The energy savings from LED troffer retrofits vary. LED retrofit kits are more efficacious than fluorescent luminaires by approximately 10%, an increase from an average of 60 to 66 lm/W.[54] LED luminaires offer higher efficacies, an average of 89 lm/W, a 44% increase over fluorescent troffers.[55]

The DLC Qualified Products List includes luminaires and retrofit kits from 70 to 138 lm/W.[56]

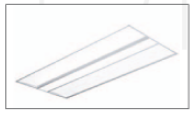
FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

Currently available LED retrofit troffers compete with existing fluorescents in terms of efficacy, glare, light distribution and color quality.[57] Keep light distribution needs in mind when selecting an LED retrofit for fluorescent troffers. Retrofit kits that use arrays of bare LEDs may provide unusual striping, unwanted additional glare and other visual issues inconsistent with the performance of existing fluorescent systems. Many retrofit products also come equipped (standard) with a dimming driver, which may not be compatible with existing dimming controls. These incompatibilities can result in flicker when dimming and a nonlinear dimming curve that may cut-off (zero light output) at low dimming levels. Consumers should consider testing any retrofit products in the existing fixture with existing controls before selecting a product for widespread retrofits.

Installation is a second factor to consider. A DOE CALiPER report confirms that retrofit kits are often incompatible with existing recessed or surface mount fixtures. Additional installation time is often necessary to modify fixtures, add wiring and perform unplanned tasks necessary to make new retrofit products work with existing fixtures.

The DLC includes retrofit kits and dedicated LED luminaires on their qualified products list and consumers should strive to select products vetted by such an organization. Safety labels should also be considered, such as whether a retrofit kit is Listed, Classified or Recognized by Underwriters Laboratories/Canadian Standards Association standards since these designations have different testing requirements.

EXAMPLE PRODUCTS: TROFFERS



Finelite High Performance Recessed LED (HPR-LED): 2x4
finelite.com/products/serieshprled-2x4-overview

- 4,018 to 7,291 lumens with 35.2 W to 74.1 W power usage
- 98 to 114 lm/W efficacy
- 83 to 87 CRI and CCT of 3,000 K, 3,500 K or 4,000 K
- Dimmable to 10%
- 68,000 hour rated life

GE Lumination LED Luminaire – BT14 Series
gelighting.com/LightingWeb/na/solutions/indoor-lighting/recessed

- 3,800 or 4,100 lumens with 43 W power usage
- 88 to 95 lm/W efficacy
- 80 CRI and CCT of 3,500 K or 4,000 K
- Non-dimmable
- 50,000 hour rated life

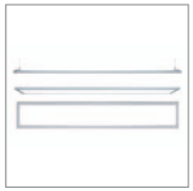
Lithonia Lighting 2RTLED Volumetric LED Luminaire
acuitybrands.com/search?keyword=troffer&attr_Product_Type=%22General%20Purpose%20Troffers%22

- 2,400 to 3,300 lumens with 24 W or 38 W power usage
- 87 to 100 lm/W efficacy
- 82 CRI and color temperature of 3,500 K, 4,000 K or 5,000 K
- Dimmable
- 50,000 hour rated life

EXAMPLE PRODUCTS: LINEAR PENDANTS

Finelite HP-4 Indirect
finelite.com/products/serieshp4-i-overview.html

- 2,901 lumens with 35.6W power usage
- 81lm/W efficacy
- 86 CRI and CCT of 3,500K
- Dimmable to 10%
- 100,000 hour rated life



Lunera Series L7 Pendant
lunera.com/seriesl7g3

- 2,584 to 3,089 lumens with 39.9W to 44.7W power usage
- 65 to 69lm/W efficacy
- 84 CRI and CCT of 3,500K
- Dimmable
- 50,000 hour rated life

Philips Ledalite Jump – Suspended LED pendant
ledalite.com/products/jump/suspended

- 2,400 lumens with 28W power usage
- 86lm/W efficacy
- 84 CRI and CCT of 3,000K, 3,500K or 4,000K
- Dimmable
- 60,000 hour rated life

CASE STUDIES

Everett Public Schools, Everett, WA

▸ bpa.gov/EE/Sectors/Commercial/Documents/everrett_SD_casestudy.pdf

The Everett Public Schools rebuilt Monroe and View Ridge elementary schools from the ground up. Cree LR24 dimmable recessed troffers were installed in the two schools' classrooms. Teachers frequently use the dimming feature in the classrooms. The control system also boosts light levels back to required levels as light output drops over time. Using LED lighting enabled the district to provide twice the minimum light level required by the Washington State Department of Health and still save energy.

San Diego State University, San Diego, CA

▸ gelighting.com/LightingWeb/na/case-studies/san-diego-state-university.jsp

San Diego State University outfitted classrooms in three buildings with GE's Lumination LED troffers. A new anatomy lab was part of the lighting project. The new LED lighting uses 50% less energy than the previously installed fluorescent fixtures. Students said classrooms felt more open and spacious and the upgrade improved environmental aesthetics.

Troffers & Surface Mounts

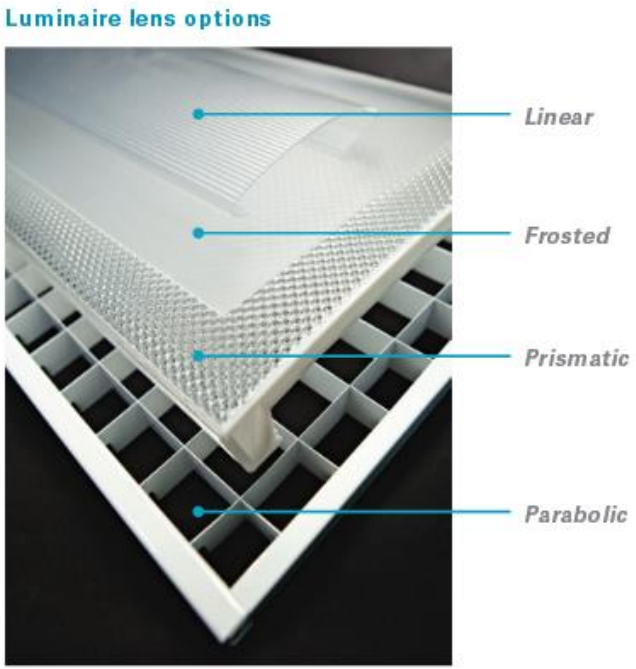
Expected Energy Savings

- Fluorescent Troffers → LED retrofit kits: 10% increase in efficacy
- Fluorescent Troffers → LED luminaires: 44% increase in efficacy

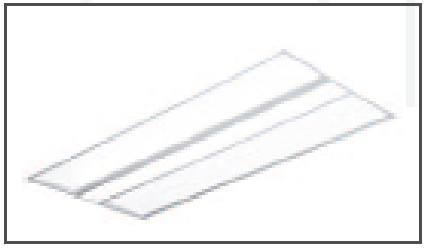
DESIGNLIGHTS CONSORTIUM®

Factors to Consider when Comparing Products

- Efficacy
- Glare
- Light Distribution
- Controls compatibility
- Retrofit kit installation requirements



Example Products: Troffers



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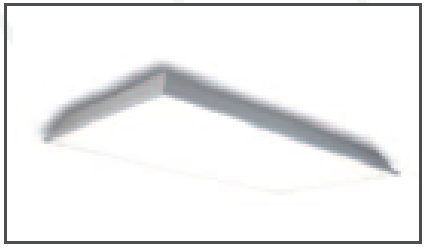

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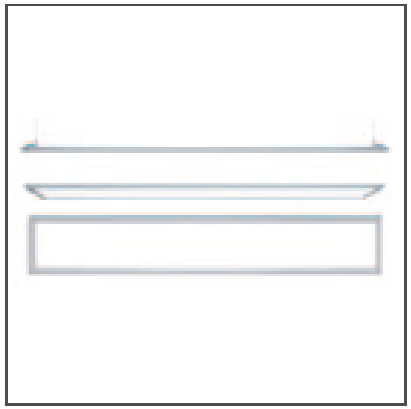

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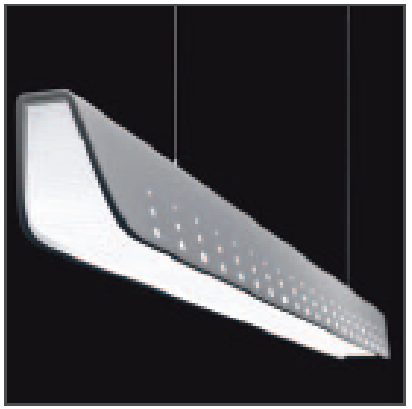

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High Bay & Low Bay Lighting

High and low bay luminaires are a type of industrial-style luminaire used to provide general illumination for applications with high ceilings (mounting height greater than or equal to luminaire spacing) or restricted ceiling heights (luminaire spacing is greater than mounting height). High and low bay luminaires may be surface-mounted or suspended.[58] These luminaires are found in commercial and industrial spaces including grocery stores, warehouses, retail storefronts, and gymnasiums.

Applications with long hours of use or lighting access challenges offer the most potential for adoption of energy-efficient LED high bay or low bay luminaires. Good retrofit opportunities may be found in spaces such as refrigerated warehouses where lighting is left on regardless of occupancy, industrial facilities with long hours of operation, and retail applications such as big box and grocery stores. LEDs are a top choice for new construction opportunities.

HID sources such as metal halide and high-pressure sodium (HPS) lamps still dominate high bay and low bay lighting applications. Sixty percent of commercial high bay lighting in California uses HID sources, according to the CSS.[59] Fluorescents and LEDs have gained some market share at 9% and 17%, respectively, according to the same study. Standard high and low bay luminaires with metal halide sources range in efficacy from 51 to 74 lm/W. Fluorescent systems range from 80 to 95 lm/W for fluorescent luminaires.[60] LED alternatives have an efficacy from 84 to 105 lm/W.[61]

EXPECTED ENERGY SAVINGS

LED technology offers significant energy savings over metal halide or other HID light sources, resulting in energy savings of 50 to 70%.[62, 63, 64, 65, 66] One study found that replacing fluorescent lighting with LED sources produced energy savings of 74%.[67] Retrofitting HID sources with LED luminaires can reap potential savings of 2,157 GWh annually, while the same with induction sources offers potential savings of 472 GWh when considered across California.[68]

The DLC list includes five categories related to high and low bay lighting. Currently, there are a total of 7,320 approved LED products across five DLC high and low bay categories.[69]

FACTORS TO CONSIDER

Access requirements and product lifespan are key considerations for high bay lighting applications, in particular. A scissor lift or other equipment is needed to access a luminaire that is more than 15 ft above the finished floor. This can increase re-lamping and maintenance costs. Consumers should compare product life and warranty information to ensure the best combination of longevity and cost.

Ambient temperature and other environmental operating conditions are another consideration. LED product performance suffers at elevated temperature. High-ceiling applications in unconditioned spaces may have elevated ambient temperatures that can reduce light output and lumen maintenance of LED solutions. If elevated ambient temperature is typical, consumers should request manufacturer's documentation about product performance in regards to operating temperature. If that information is unavailable, consumers should consider derating an LED high bay's light output by 10% before making product comparisons to account for reduced performance at elevated temperatures.

Controls compatibility should be closely reviewed when considering LED high and low bay luminaires. LED solutions are more compatible with occupancy, daylighting and tuning control strategies as compared to HID solutions. Consumers should compare the controllability of proposed LED products against their space's control needs. With recent changes in Title 24, more high and low bay lighting retrofits must comply with multi-level dimming and controls requirements. Consumers should compare LED products against these needs.

Table 2. Design Light Consortium Qualified Products List Requirements for High-Bay and Low-Bay Lighting Application Categories

Application	Minimum Light Output	Zonal Lumen Density	Minimum Luminaire Efficacy	Allowable CCTs	Minimum CRI	L70 Lumen Maintenance
High Bay Luminaires for Commercial and Industrial Buildings	10,000 lm	≥ 30%: 20–50°	80 lm/W	≤ 5,700 K	70	35,000 hrs
Low Bay Luminaires for Commercial and Industrial Buildings	5,000 lm	≥ 30%: 20–50°	80 lm/W	≤ 5,700 K	70	35,000 hrs
High-Bay Aisle Luminaires	10,000 lm	≥ 50%: 20–50° ≥ 30%: 0–20°	80 lm/W	≤ 5,700 K	70	35,000 hrs
Retrofit Kits for High-Bay Luminaires for Commercial and Industrial Buildings	10,000 lm	≥ 30%: 20–50°	80 lm/W	≤ 5,700 K	70	35,000 hrs
Retrofit Kits for Low-Bay Luminaires for Commercial and Industrial Buildings	5,000 lm	≥ 30%: 20–50°	80 lm/W	≤ 5,700 K	70	35,000 hrs

EXAMPLE PRODUCTS

Cooper Industries HB LED Series
cooperindustries.com/content/public/en/lighting/products/highbay_lowbay_industrials/led.html

- 129 lm/W efficacy
- 85 CRI and CCT of 4,000 K and 5,000 K
- Can be used in variety of applications and mounting heights
- Dimmable luminaire with various options for light distribution, sensors, lumens and CCT
- Available with integrated occupancy sensor
- 60,000 hour rated life

GE Albeo LED ABHX Series
gelighting.com/LightingWeb/na/solutions/indoor-lighting/albeo-led-luminaire-abhx.jsp

- 6,000 to 60,000 lumens with 250 W to 1,500 W
- 70+ CRI with 4,000 K or 5,000 K CCT
- 0 to 10 V Dimming
- 100,000 hour rated life
- Modular design with 1 to 6 modules
- High and low bay lighting in warehouses, cold storage, industrial settings, gymnasiums, retail spaces or high-ceiling spaces
- Daylight, motion and wireless controls

Lithonia Lighting PROTEON SL Linear LED High Bay
lithonia.acuitybrands.com/Proteon-SL/Proteon-SL.aspx

- 3,600 to 7,200 lumens with 47 W to 92 W
- 83 CRI with 3,500 K, 4,100 K and 5,000 K CCT
- 4 ft or 8 ft linear rail
- Incorporates occupancy and photocell sensing into luminaire

CASE STUDIES

Ace Hardware Distribution Center, Rocklin, CA

- etcc-ca.com/sites/default/files/reports/ET12PGE3361%20LED%20High-Bay%20Lighting%20and%20Controls%20Assessment.pdf

The high bay lighting at an Ace Hardware Distribution Center was retrofitted from metal halide luminaires to LED luminaires. One hundred and two 400W metal halide luminaires were replaced with 230W LED luminaires with built-in wireless interconnectivity, occupancy sensing and daylight sensing. Retrofitting the luminaires to LEDs alone reduced energy use about 50%. Using combined daylighting and fine granular occupancy sensors could cut another 43% in energy use.

San Jose Washington Unified Youth Center Gymnasium, San Jose, CA

- etcc-ca.com/sites/default/files/reports/ET11PGE1151_SJ%20WUYC%20Gym%20LED%20Final%20Report%202013-05-17.pdf

Thirty 200W BritePointe high bay LED luminaires were installed to replace metal halide luminaires at the San Jose Washington Unified Youth Center gymnasium. The project saved an estimated 9,941 kWh or $1,650 annually as compared to the fully functional incumbent system. The project improved lighting uniformity and significantly improved light levels.

Blue Diamond Growers Refrigerated Warehouse, Sacramento, CA

- smud.org/en/business/save-energy/energy-management-solutions/documents/Blue-Diamond-Phase-1.pdf

LED luminaires with motion sensors were installed at a Blue Diamond Growers refrigerated warehouse as part of a project to save energy, cut costs, improve lighting quality, and increase control. Seventy-seven 160W LED luminaires from Albeo Technologies replaced 77 400W HPS luminaires. The total annual energy savings was 79%, or 236,477 kWh. The estimated utility bill reduction was $21,755.

High Bay & Low Bay Lighting

Expected Energy Savings

Metal Halide/HID → LED: 50 – 70% Savings

DESIGNLIGHTS CONSORTIUM

Factors to Consider when Comparing Products

- Access requirements
- Product Lifespan
- Ambient Temperature
- Controls Compatibility

High Bay & Low Bay Lighting

Example Products

Cooper Industries HB LED Series
cooperindustries.com/content/public/en/lighting/products/highbay_lowbay_industrials/led.html

- 129 lm/W efficacy
- 85 CRI and CCT of 4,000K and 5,000K
- Can be used in variety of applications and mounting heights
- Dimmable luminaire with various options for light distribution, sensors, lumens and CCT
- Available with integrated occupancy sensor
- 60,000 hour rated life

GE Albeo LED ABHX Series
gelighting.com/LightingWeb/na/solutions/indoor-lighting/albeo-led-luminaire-abhx.jsp

- 6,000 to 60,000 lumens with 250 W to 1,500W
- 70+ CRI with 4,000K or 5,000K CCT
- 0 to 10V Dimming
- 100,000 hour rated life
- Modular design with 1 to 6 modules
- High and low bay lighting in warehouses, cold storage, industrial settings, gymnasiums, retail spaces or high-ceiling spaces
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Parking Garage Luminaires

Parking garages face unique challenges with their lighting. A mix of pedestrians and vehicles traffic within the confined garage space creates an environment that demands adequate, reliable lighting to ensure public safety and minimize accidents. Parking garages should provide ample lighting to mitigate these issues, while also minimizing glare and light trespass.

Parking garages are classified as indoor spaces under state lighting regulations, but they use many of the same lighting technologies as outdoor parking lots, and they often provide excellent opportunities to reduce lighting energy waste. Unlike lots, parking garages have special lighting requirements for illuminating entrances and exits, ramps, perimeters, and stairways. To meet safety and security needs, many garages employ lighting systems that operate continuously, regardless of actual occupancy or available daylight. Doing so wastes energy, contributes to peak demand during the day, and contributes to light pollution at night.

Parking garage lighting typically employs fluorescent or HID light sources such as HPS and metal halide lamps. LEDs are an increasingly preferred option over these traditional solutions because of their long life, low maintenance, high efficacy, better light quality and controls compatibility. All these reduce cost for facility managers and building owners. HID and fluorescent solutions used in garage lighting applications[70] typically have an efficacy range of 50 to 80 lm/W,[71] while LED replacement options provide approximately 70 to 100 lm/W.[72]

ENERGY SAVINGS

Parking structure lighting accounts for approximately 1,102 GWh of California's annual electricity use.[73] Implementing parking garage luminaires with integrated controls or networked controls and high-efficiency light sources produces a range of energy savings depending on the technology being replaced. Studies show LED luminaire replacement typically offers energy savings between 30% and 90%.[74, 75, 76] Across California, one study estimates that replacing linear fluorescent lighting (20% of lighting in covered parking) with LED luminaires offers potential annual energy savings of 55 GWh annually, and replacing high-intensity discharge luminaires (80% of lighting in covered parking) with LED sources can provide 413 GWh of potential annual energy savings.[77] Adding bi-level occupancy sensing to existing linear fluorescent luminaires offers a potential energy savings of 50 GWh annually across the state.[78]

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

Consumers should consider adding lighting controls for any garage lighting retrofit or new construction project. Title 24, Part 6 includes mandatory measures requiring occupancy and daylighting controls for most parking garage projects that trigger code compliance. However, high performing systems can achieve savings that exceed lighting power density requirements and include advanced controls that surpass code measures. Installing luminaires paired with occupancy controls will significantly cut energy use during vacant periods. Incorporating networked controls will also maximize system savings since facility managers can employ dynamic tuning, scheduling and optimized occupancy-based dimming down to the individual luminaire level. Networked control systems can also facilitate participation in utility demand response programs. Current energy code requirements do not require demand response control systems for parking garages. Garage facilities are an excellent application for demand response because lighting can often be reduced during daytime hours with no impact to the visual environment.

When considering such systems, consumers should be aware of the communication and control platform of the controls system. Some wireless control solutions can have difficulty transmitting signals through the concrete and steel garage structure. Consumers should discuss the proposed application with control system providers to ensure performance in the intended application and specific installation location.

EXAMPLE PRODUCTS

Kenall TexDek for Parking Garages

kenall.com/Products/Product-Detail.htm?DataID=16157

- 65 CRI available with 4,000K, 5,000K and 5,700K CCT
- 17-inch diameter ceiling mount LED luminaire
- Uplight feature to eliminate cave effect
- Textured lens to reduce glare
- Option to include integral occupancy/light sensor with or without associated control module
- Can integrate with a remote control module for networked lighting

Cree Edge Parking Structure Luminaire

cree.com/Lighting/Products/Outdoor/Parking-Structure/THE-EDGE-Parking-Structure

- Improved color rendition and lighting uniformity
- Integrated bi-level occupancy sensor that can yield 80% energy savings while still maintaining 50% lumens at half-power operation

Archway Passage VAP LED by Acuity Brands

lithonia.com/commercial/vap+led.html

- 4,000 to 12,000 lumens with 39W to 114W power usage
- CRI of 80 and 90 with CCT of 3,500K, 4,000K and 5,000K
- Wireless bi-level or variable dimming with optional onboard sensors
- Available with optional motion sensor

CASE STUDIES

Multiple Locations in CA

▸ cltc.ucdavis.edu/publication/adaptive-led-parking-garage-luminaires

Bi-level LED parking garage luminaires replaced HPS luminaires at three locations in California. Cree's Edge Series luminaires replaced 30 HPS luminaires at California State University, Sacramento (CSUS). The existing luminaires operated at 189W each, while the LED luminaires used between 165W and 77W, depending on whether they were in high or low mode. The total energy savings was 68%. At California State University, Long Beach, Cree luminaires replaced seven 189W HPS luminaires. These LEDs consumed 47W in high mode and 16W in low mode. The retrofit produced 84% energy savings. Twenty-three 210W HPS luminaires were replaced with Philips VizorLED luminaires at Civic Center Garage in San Marcos, CA. The new luminaires consumed 70W in high mode and 7W in low mode. The retrofit produced 81% energy savings.

Parking Garages, Sacramento, CA

▸ smud.org/en/business/save-energy/energy-management-solutions/documents/bi-level-LED-aug10.pdf

Two parking garages in Sacramento, CA were retrofitted with bi-level LED fixtures. CSUS replaced 150W HPS luminaires with 32 Cree luminaires with WattStopper passive infrared occupancy sensors. The new luminaires operated at 77W in low mode and 165W in high mode. The energy savings was 36%. The City of Sacramento replaced 175W metal halide and mercury vapor luminaires with 25 Cree luminaires with integrated passive infrared occupancy sensors. The new luminaires operated at 39.5W in low mode and 118.5W in high mode. The project provided higher illumination levels and 67% in energy savings.

U.S. Department of Labor Headquarters Parking Garages, Washington, D.C.

▸ apps1.eere.energy.gov/buildings/publications/pdfs/ssl/deptoflabor_brief.pdf

The parking garages at the U.S. Department of Labor headquarters in Washington, D.C. were lighted using 300 HPS luminaires. For a demonstration project, 19 of them were replaced one-for-one with LEDs. Each LED luminaire had an integral occupancy sensor that controlled their output through bi-level dimming. Switching to LED produced energy savings of 52%, which increased to 88% by using occupancy sensor controls.

Parking Garage Luminaires

Expected Energy Savings

Incumbent → LED: 30 - 90% Savings

Well suited for bi-level controls → additional savings!

Factors to Consider when Comparing Products

Controls compatibility

- Exceeding code requirements of occupancy and daylight harvesting

Parking Garage Luminaires

Example Products

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kenall.com/Products/Product-Detail.htm?DataID=16157

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cree.com/Lighting/Products/Outdoor/Parking-Structure/THE-EDGE-Parking-Structure

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lithonia.com/commercial/vap+led.html

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Interior LED Product Types

Omnidirectional (A19) Lamps

Recessed Downlights

Directional Lamps

Troffers & Surface Mounts

Tubular LEDs

High-Bay & Low-Bay Lighting

Track Lighting

Parking Garage Luminaires

OUTDOOR LED LUMINAIRES

Outdoor LED Product Types

Wall Packs

Pole-Mounted Parking & Area

Factors to Consider

Wall Packs

Pole-Mounted Parking & Area

- Design Criteria
  - Consider energy efficiency, safety and user comfort
  - Light Distribution
  - BUG Rating for each application
- Controls Compatibility
  - Delivering the right amount of light – when you need it, where you need it!
  - Sensor Coverage for each application

Wall Packs

Wall packs, or exterior wall-mounted fixtures, may be found in both residential and commercial applications. Wall packs offer an effective means of illuminating building perimeters, bolstering security and aiding wayfinding. In residential applications, wall packs are most often used for porches, garage perimeters or other non-aesthetic locations. In commercial applications, wall packs typically operate in areas with low occupancy rates, which wastes energy by illuminating vacant outdoor spaces for hours every night.

Wall packs most often employ HID light sources, such as HPS and metal halide lamps. LED alternatives provide a more efficacious, longer life product that is compatible with occupancy controls, step dimming curfew controls, or other advanced outdoor control strategies. The efficacy for LED wall packs ranges from approximately 80 to 100 lm/W[79] compared to HID sources which deliver just 25 to 80 lm/W.79[80]

EXPECTED ENERGY SAVINGS

Adding outdoor occupancy or curfew dimming controls should be considered for any LED wall pack retrofit. Manufacturers now offer products with integrated sensors, which reduce installation time in the field. Incorporating wall packs into a networked control system maximizes energy savings by providing a way to analyze and adjust power usage based on occupancy patterns and provides other benefits.

Statewide, wall packs use approximately 336 GWh annually.[81] One study found that replacing incumbent sources such as metal halide and HPS wall packs with LED luminaires and occupancy sensors produced energy savings up to 89%.[82] The energy savings will depend on the technology being replaced, the types of controls included and the occupancy rate of the illuminated area. Replacing existing HID wall packs with LED luminaires can potentially save 208 GWh per year in California.[83]

To surpass the Title 24, Part 6 requirements, motion sensors should be included in all wall packs, regardless of maximum rated wattage or mounting height (within the limitations of the range of the sensor selected to pair with the luminaire).

EXAMPLE PRODUCTS

Crosstour MAXX LED Wall Pack/Area Site Luminaire

cooperindustries.com/content/public/en/lighting/products/outdoor_wall_mount_lighting/_829374.html

- 4,400 to 7,370 lumens with 41 W to 81 W power usage
- 65 to 70 CRI and CCT of 5,000 K or 3,500 K
- Wall, inverted or pole mount luminaire to replace up to 400 W HID luminaire
- Available with dimming and occupancy sensors
- Five-year warranty

Philips 121 Line LED Sconce

sitelighting.com/literature/g_121_G2_led_sconce_broc.pdf

- 5,000+ lumens with 18 W to 75 W power usage
- Available in CCT of 4,000 K
- 0 to 10 V dimming
- Available with optional motion sensor
- Five-year warranty

Leotek Economy Sconce Wall Pack

- 2,410 to 7,300 lumens with 28 W to 84 W power usage
- 86 to 88 lm/W efficacy
- 70 CRI and CCT of 3,000 K, 4,000 K and 5,000 K
- Dimmable to 50%
- 10-year warranty

CASE STUDIES

University of California, Davis, CA

▸ cltc.ucdavis.edu/publication/adaptive-led-wall-packs-uc-davis

UC Davis replaced metal halide and HPS wall packs on campus with dimmable LED luminaires (Philips WTM-40W) with occupancy sensors (WattStopper EW low-voltage outdoor motion sensor) and wireless controls (Lumewave, an Echelon Company, TOP900-TL). The 101 LED wall packs operate at 20% power when the space is unoccupied and switch to higher illuminance when needed. The LED luminaires use 14 W in low mode and 45 W in high mode. The installation reduced energy use 89% based on a 20% occupancy rate. Annual energy and maintenance cost savings is estimated to be approximately $900 per fixture.

Racine Water and Wastewater Treatment Plant, Racine, WI

▸ e-conolight.com/case-study-wastewater-utility-plant

The Racine Water and Wastewater Treatment Plant used 78 38 W LED wall packs from E-conolight to replace 50 W and 70 W HPS fixtures above the exterior doorways of the plant's 17 buildings. Electricity savings is estimated to be up to 50% for some installations. Quality of light and a uniform appearance were also factors for the switch.

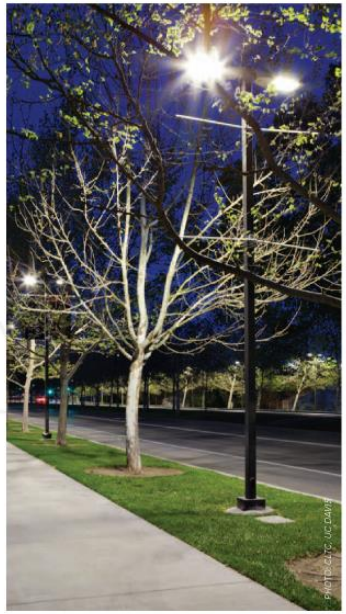
Industrial Developments International, Jurupa Valley, CA

▸ cooperindustries.com/content/dam/public/lighting/resources/library/case_studies/led_solutions/Jurupa-Valley-California-ADH131318.pdf

Industrial Developments International selected LED solutions from Eaton's Cooper Lighting business as part of an effort to reduce energy costs while providing lighting that satisfied safety and security issues. The project provided proper illumination for the facility's exterior and parking lot and produced total energy savings of more than 50% compared to metal halide equivalents. Lumark Crosstour LED wall pack luminaires were used for wall-mounted applications. The fixtures, which use just 30 total watts, offered comparable light levels to that of 175 W metal halide products.

Pole-Mounted Parking & Area

Pole-mounted luminaires are used in outdoor applications to provide area lighting for walkways, illuminate parking lots and serve as security lighting. Existing outdoor parking and area lighting typically uses HID lighting,[84] with an overall luminaire efficacy range of 50 to 100 lm/W for HPS and metal halide sources.[85] LED outdoor parking and area luminaires are energy-efficient, environmentally friendly alternative to traditional solutions. Past studies predicted LEDs to achieve efficacies of approximately 200 lm/W for low CRI devices and 130 lm/W for very high CRI devices by 2027.[86] Improvements are progressing faster than these predications. Currently, LED parking and area luminaires have luminaire efficacy ranging from 80 to 110 lm/W. They can deliver better light quality and controls compatibility than HID products.



EXPECTED ENERGY SAVINGS

In 2012, area lighting comprised 3,800 GWh of California's commercial energy usage, of which 1,363 GWh was pole-mounted parking lighting and 1,015 GWh was public area lighting.[87] Replacing existing parking lot and area lighting with LED alternatives can achieve significant energy use reductions, particularly when the luminaires are controlled by occupancy sensors. One study found savings between 51% and 83% in a test case for replacement of the light source, depending on the technology implemented as the retrofit option.[88, 90] Replacing existing HID parking lighting with LEDs offers potential energy savings of 749 GWh across the state. The long lifetime of LEDs also means lower maintenance costs. Lamp replacement is costly for pole-mounted luminaires.

EXAMPLE PRODUCTS

GE Evolve Scalable Project Grade Cobrahead
gelighting.com/LightingWeb/na/solutions/outdoor-lighting/roadway/evolve-led-project-grade-scalable-cobrahead.jsp

- Designed to preserve aesthetics of typical cobrahead luminaires
- 70 CRI with 4,000 K and 5,000 K options available
- 50,000 hour lifetime
- Photosensors available

Lithonia Lighting D-Series Area Size 2 LED Area Luminaire
lithonia.com/commercial/d-series+area+size+2.html

- Area luminaire with CCT of 3,000 K, 4,000 K or 5,000 K and CRI of 80, 70 or 65 respectively
- Available with dimming driver, ROAM compatibility, dual switching, motion sensing and bi-level switched dimming to 30% or 50%

Philips Hadco LumiLock LED GX2 Post Top
hadco.com/Hadco/Public/ProductDetail.aspx?pid=3996

- Post top luminaire
- 3,000 K, 4,000 K or 5,700 K CCT
- 60,000 hour lifetime
- Nine standard dimming schedules available. Custom dimming also available

CASE STUDIES

Raley's Supermarket, West Sacramento, CA
▸ eere.energy.gov/buildings/publications/pdfs/ssl/gateway_raleys.pdf

Bi-level LED luminaires from Cree, Inc. replaced 16 pole-mounted metal halide luminaries in a Raley's Supermarket parking lot. The new luminaires included motion sensors enabling the lighting to switch between high and low mode depending on the occupancy of the space. The annual energy savings was 1,056 kWh.

Resource Conservation District, Lakeside, CA
▸ etcc-ca.com/sites/default/files/OLD/images/parking_lot_led_lighting_assessment.pdf

The Resource Conservation District installed seven LED luminaires instead of metal halide luminaires for its new parking lot lighting, reducing annual energy use by 52%. The annual energy cost savings was $886.

Wall Packs

Expected Energy Savings

- Metal Halide/HPS → Bi-Level LED: 89% Savings

Pole-Mounted Parking & Area

Expected Energy Savings

- Metal Halide/HPS → Occupancy Controlled LED: 51 – 83% Savings

Wall Packs

Example Products

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cooperindustries.com/content/public/en/lighting/products/outdoor_wall_mount_lighting/_829374.html

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- 50,000 hour lifetime
- Photosensors available

Lithonia Lighting D-Series Area Size 2 LED Area Luminaire

lithonia.com/commercial/d-series+area+size+2.html

- Area luminaire with CCT of 3,000K, 4,000K or 5,000K and CRI of 80, 70 or 65 respectively
- Available with dimming driver, ROAM compatibility, dual switching, motion sensing and bi-level switched dimming to 30% or 50%

Philips Hadco LumiLock LED GX2 Post Top

hadco.com/Hadco/Public/ProductDetail.aspx?pid=3996

- Post top luminaire
- 3,000K, 4,000K or 5,700K CCT
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Wall Packs

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UC Davis replaced metal halide and HPS wall packs on campus with dimmable LED luminaires (Philips WTM-40W) with occupancy sensors (WattStopper EW low-voltage outdoor motion sensor) and wireless controls (Lumewave, an Echelon Company, TOP900-TL). The 101 LED wall packs operate at 20% power when the space is unoccupied and switch to higher illuminance when needed. The LED luminaires use 14W in low mode and 45W in high mode. The installation reduced energy use 89% based on a 20% occupancy rate. Annual energy and maintenance cost savings is estimated to be approximately $900 per fixture.

Racine Water and Wastewater Treatment Plant, Racine, WI

- e-conolight.com/case-study-wastewater-utility-plant

The Racine Water and Wastewater Treatment Plant used 78 38W LED wall packs from E-conolight to replace 50W and 70W HPS fixtures above the exterior doorways of the plant's 17 buildings. Electricity savings is estimated to be up to 50% for some installations. Quality of light and a uniform appearance were also factors for the switch.

Industrial Developments International, Jurupa Valley, CA

- cooperindustries.com/content/dam/public/lighting/resources/library/case_studies/led_solutions/Jurupa-Valley-California-ADH131318.pdf

Industrial Developments International selected LED solutions from Eaton's Cooper Lighting business as part of an effort to reduce energy costs while providing lighting that satisfied safety and security issues. The project provided proper illumination for the facility's exterior and parking lot and produced total energy savings of more than 50% compared to metal halide equivalents. Lumark Crosstour LED wall pack luminaires were used for wall-mounted applications. The fixtures, which use just 30 total watts, offered comparable light levels to that of 175W metal halide products.

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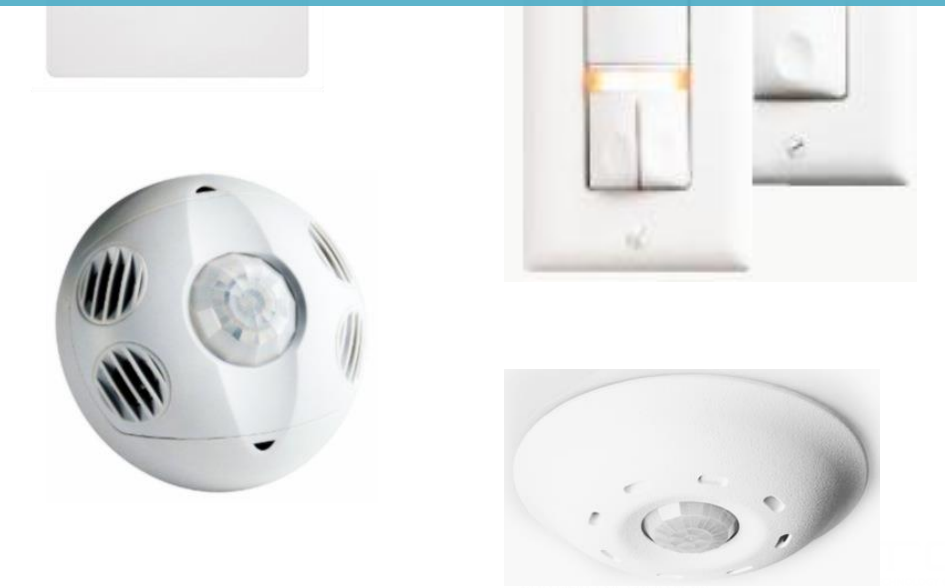
LIGHTING CONTROLS



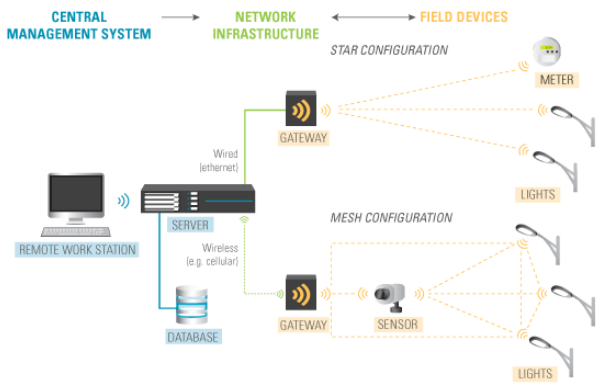
task/low-ambient strategy be used to comply. By encouraging the adoption of networked systems that can discretely control smaller zones and layers of lighting rather than just ambient lighting, lighting energy use can be measured and managed for maximum sustained savings. The Title 24, Part 6 standards offer control credits by applying the Power Adjustment Factors listed in Table 140.6-A for integrating occupancy controls in zones up to 125 ft², from 126 ft² to 250 ft², and from 251 to 500 ft². Even zones larger than 500 ft² could result in reductions.[93]

Occupancy-based controls in any of these ranges would exceed code requirements. Using networked lighting systems to implement this strategy may also support measures beyond lighting and include the controlled outlet measures for office applications in the new Electric Power Distribution Systems requirements in Section 130.5 of the Title 24, Part 6 standards. By tying the occupancy sensors to the outlets as well as lighting in retrofit projects that may not have triggered Section 130.5, both lighting power and plug load reductions could be achieved.

NETWORKED LIGHTING CONTROL SYSTEMS

A networked lighting control system combines software and hardware to deliver lighting commands from a command station to the light sources in the system. A networked control system uses either a wireless or wired communication platform to transfer information between system components. Radio frequency is the typical communication platform for wireless systems, and power line carrier is the typical communication platform for wired systems. Select systems use a combination of the two platforms to create a reliable and flexible communication network for all applications. This diagram illustrates the communication network for an outdoor wireless networked lighting system.

Through the communication network, lighting control systems can automatically adjust light levels based on occupancy patterns, available daylight, optimized schedules, institutional tuning, demand response signals, the energy management needs of a building, and personal control.



The lighting should be equipped with dimmable light sources to maximize the potential lighting energy savings. Dimmable lighting technologies allow for light levels to be reduced using digital or analog control signals communicated through the network control system. These signals can respond to environmental sensors such as occupancy and daylighting or through defined schedules that vary the light levels over the course of a day.

Networked systems typically have a higher cost of implementation when compared with devices that offer only local control of luminaires in the same room or area. Networked control systems that use software to collect accurate data on occupancy rates and energy use over time have great potential to encourage and reward implementation if the cost of the system is acceptable. Utility programs that rewarded verifiable long-term reductions would encourage adoption.

EXPECTED ENERGY SAVINGS

A report describing the changes in the installed lighting market in the U.S. in 2010 provided potential energy savings for typical lighting control strategies:[94]

- Occupancy controls: 8% to 38%
- Daylighting controls: 17% to 38%
- Personal tuning: 10% to 50%
- Institutional tuning: 18% to 53%
- Combined multiple types of controls: 19% to 56%

Specific to outdoor lighting applications, traditional exterior lighting design practice is limited to constant light output based on "worst case" conditions, which over-illuminates exterior areas and wastes energy. Roadway and area lighting account for approximately 87%of the energy use in exterior stationary lighting in the U.S., yet few installed luminaires include advanced controls to adjust light output to appropriate recommended levels based on measured environmental conditions.

The Title 24, Part 6 standards include control requirements achievable by implementing a networked control system. Doing so provides system owners the flexibility to reconfigure the system, reaping deeper energy savings than required. The Title 24, Part 6 standards do not require that a networked control system be used to comply. CLTC developed a guide, "What's New in the 2013 Code?" to offer an overview of important requirements and major updates to the Title 24, Part 6 lighting code. The guide is here: **cltc.ucdavis.edu/publication/whats-new-title24-2013-code**

FACTORS TO CONSIDER WHEN COMPARING PRODUCTS

When comparing networked lighting products, evaluate traditional control capabilities such as scheduling, occupancy and daylighting features. Consider advanced control capabilities such as energy monitoring and demand response. Advanced controls may have specific system installation requirements and staff education may be needed for long-term maintenance.

Traditional control capabilities are enabled by environmental sensors, such as occupancy and daylighting sensors. For indoor applications, a variety of occupancy sensor technologies should be available for varying space types within the typical building. PIR and ultrasonic technologies are typically used in tandem to provide full coverage of a building. Microwave-based occupancy sensor technology is in development to address PIR and ultrasonic limitations in the outdoor environment.

Approaches to energy monitoring vary from system to system, based on the location of the on-board meter(s) and the accuracy of the meter(s). Energy monitoring strategies that vary in accuracy are true power, apparent power and correlated power. Before purchasing a control system, prospective buyers should clarify which approach a control manufacturer uses to ensure it is capable of the achieving the level of accuracy needed for their needs, such as specific utility incentive programs.

Control systems with ADR features allow system owners to participate in utility incentive programs by allowing lighting authorized by the system owner to automatically dim in response to a signal generated and delivered to the system by the utility. This approach is in contrast to a traditional lighting system that requires a facility manager to manually accept the utility message and dim the lights at the site in order to receive the utility incentive. For some applications, demand response capabilities are required by code. For facilities with less manpower, ADR is a viable path to compliance.

Manufacturer or trade association training programs for networked lighting control products, such as the National Advanced Lighting Control Training Program, are recommended for installation teams to familiarize themselves with new control systems. An alternate installation model networked lighting control system manufacturers use is to coupling the installation with its distribution by using Value Added Retailers exclusively to sell, install and maintain their products.

PRODUCT EXAMPLES

ControlScope by Daintree Networks

daintree.net/products/lighting-controls

- The Wireless Area Controller centrally manages the network, communicating with compatible third party sensors, wall switches, ballasts, LED drivers and fixtures.
- The product uses Daintree's ZigBee wireless mesh network instead of control panels and wiring to ease installation and maintenance. A wireless adapter enables third-party lighting control devices to communicate with the controller.
- ControlScope Manager, a web-based application, allows facility managers to apply scheduling, occupancy sensing, and demand response. Commands can be applied wirelessly to individual fixtures or across a building.

WattStopper Digital Lighting Management

wattstopper.com/products/digital-lighting-management.aspx

- The product provides load control devices, occupancy sensors, personal controls, daylighting sensors, interfaces, and configuration tools and its own network control and monitoring system.
- It is built on open standards, making each control point in the system accessible.
- It provides easy integration with other systems including audiovisual, motorized shades and HVAC.

Enlighted

nlightedinc.com/solutions/products

- Enlighted Smart Sensors connect to each light fixture in the building to gather energy consumption data. Once configured, the sensors control each light fixture without requiring centralized control.
- Enlighted Gateway enables Smart Sensors and Energy Manager to communicate.
- Enlighted Energy Manager monitors, analyzes and reports on energy savings using a web-based interface.

nLight by Acuity Brands

nlightcontrols.com/lighting-controls/overview

- It connects digital devices, occupancy sensors, photocells, power/relay packs, wall switches, dimmers, panels, and luminaires.
- Every device in the network is individually accessible and can make its own switching and dimming decisions. It eliminates layering lighting control devices by using relays built into sensors and power packs to switch local lighting circuits.

Lumewave by Echelon

echelon.com/applications/pl-outdoor-lighting

- A mesh network lighting control system allows easy adjustment of lighting schedules, luminaire groupings and light levels, and also gathers revenue-grade energy metering data, and receives automated maintenance alerts
- The system luminaires are controlled by a photocell, time-clock, and motion sensor (PIR or long-range microwave)
- Long-range outdoor microwave sensor that can distinguish between slow and fast moving objects of varying sizes, such as pedestrians, cyclists and motor vehicles
- Combined power line and radio frequency-based solution, providing the benefits of both architectures

CASE STUDIES

University of California, Davis, CA

▸ cltc.ucdavis.edu/publication/speed-case-study-campus-wide-networked-adaptive-led-lighting-uc-davis

UC Davis installed more than 1,500 network-controlled LED streetlights, area lights, post-tops, and wall packs. The luminaires are controlled by occupancy sensors and connected through a radio-frequency mesh network. The control system has a direction of travel feature that allows it to tailor light levels according to occupants' rate and direction of travel, maximizing energy savings and safety. Facility managers can monitor energy use and occupancy patterns, receive automated maintenance alerts, and adjust lighting schedules, all from a laptop computer. The lighting system reduced the campus' exterior lighting use by 86% (1,231,758 kWh annually) and saved $120,900 in annual energy and maintenance costs.

NorthBay VacaValley Hospital, Vacaville, CA

▸ cltc.ucdavis.edu/publication/networked-adaptive-exterior-lighting-health-care-sector

An outdoor networked lighting system was installed at the NorthBay VacaValley Hospital. Dimmable LED luminaires were installed in parking lots, walkways, and emergency vehicle routes, replacing 40 induction luminaires, 13 HPS luminaires and seven metal halide luminaires. Motion sensors provided maximum coverage, ensuring lights operated at sufficient levels when occupants were detected and used less energy when areas were vacant. A lighting control network enabled facility managers to adjust lighting schedules, light levels, monitor the system's energy use, and receive automated maintenance alerts. The retrofit reduced lighting energy use by 66% and dramatically reduced lighting maintenance needs.

Tri Tool, Rancho Cordova, CA

▸ smud.org/en/business/save-energy/energy-management-solutions/documents/Tri-Tool-Advanced-Lighting-Controls.pdf

Tri Tool retrofitted lighting in the warehouse and office areas at its facility. Metal halide luminaires were replaced with LED high bay luminaires including dimmable drivers and motion sensor controls. All fluorescent luminaires in the office areas, bathrooms and hallways were replaced with dimmable LED luminaires. Daintree provided the wireless network communications and lighting controls software. The total annual energy savings was 191,316 kWh per year or 86%. The estimated energy cost savings was $21,699 per year.

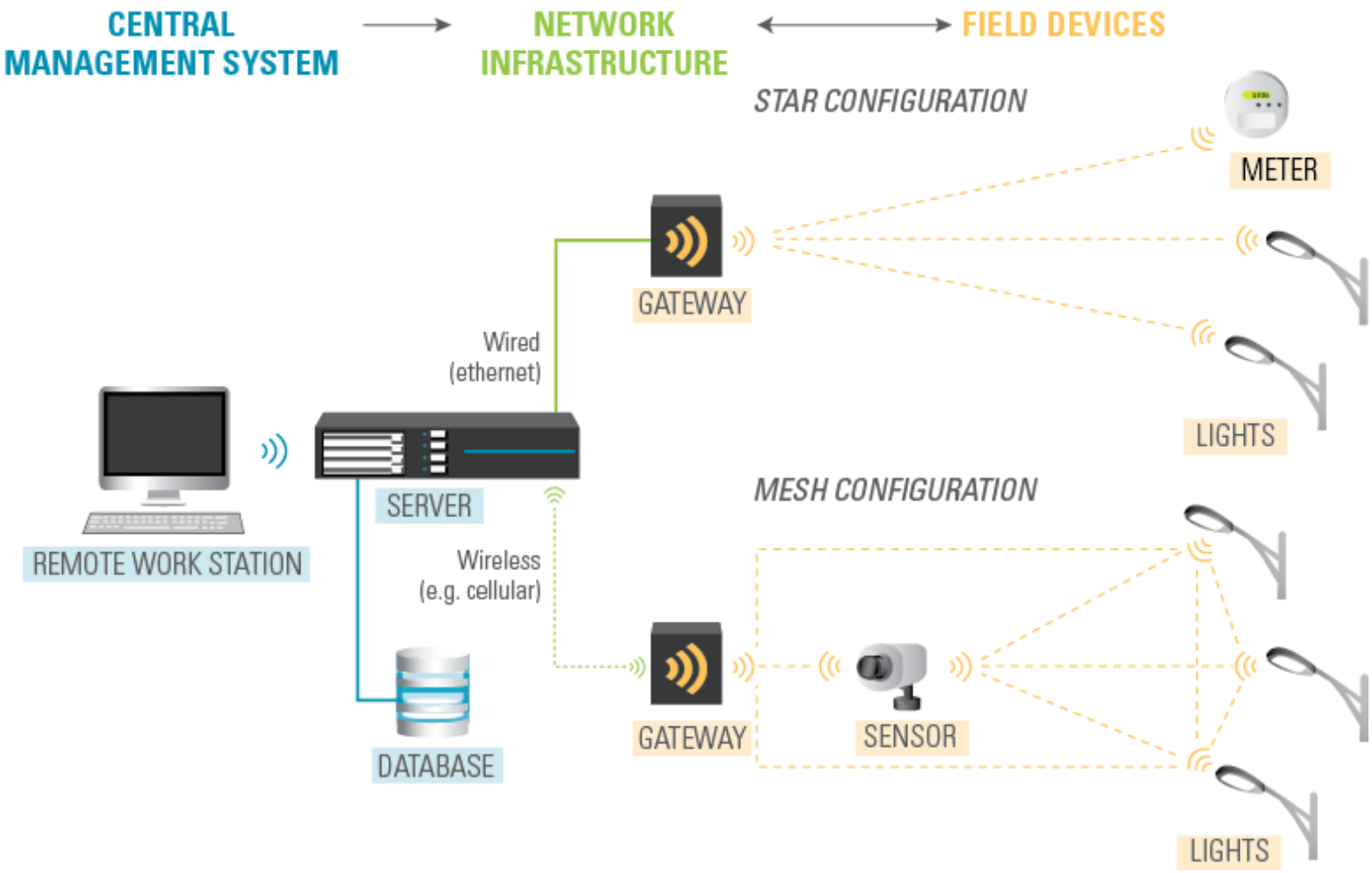
Introduction to Lighting Controls

- **Occupancy Control Strategies (8-38% Expected Energy Savings)**
  - Motion detecting sensors reduce electric lighting by reducing light levels when the space is vacant.
- **Daylight Control Strategies (17 – 38% Expected Energy Savings)**
  - Photosensors reduce dimmable electric lighting in response to available daylight in a building interior.
- **Personal Tuning (10 – 50% Expected Energy Savings)**
  - Similar to manual control, the traditional form of lighting control that is user defined at the switch or dimmer level.
- **Institutional/Task Tuning (18 – 53% Expected Energy Savings)**
  - Controls reduce light levels to provide adequate illuminance for the typical task performed in the space.
- **Scheduling**
  - Time clock features allow for automated lighting control, switching or dimming lighting at predefined points in time based on a user defined schedule.
- **Lumen Maintenance**
  - Reduces the initial light level of a new lighting system, increasing the light output over its life to maintain illuminance levels as the light source degrades.

Unconventional Applications for Lighting Controls

- Outdoor occupancy sensors now exist that can serve applications with **outdoor lighting mounted 24 feet or more above grade**.
- By supporting the adoption of networked lighting controls systems, there is also the opportunity to stimulate the implementation of lighting systems that can **automatically respond to a demand response signal** beyond the requirements in the Title 24, Part 6 2013 standards.
- Adding **occupancy-based controls or fine-tuned scheduling controls to sales canopies, building facades, building perimeters, parking and area lighting and signage** for fuel and convenience stores
- Significant energy and maintenance savings can be achieved by using a **combination of low ambient lighting, zonal controls for smaller areas and high-quality task lighting and personalized controls** in open office environments.

Networked Lighting Control Systems

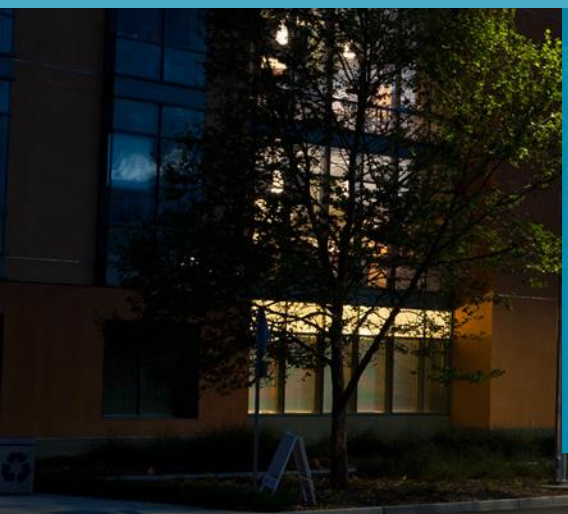


Networked Lighting Control Systems

Factors to Consider when Comparing Products

- Traditional Features
  - Scheduling
  - Occupancy
  - Daylighting
- Advanced Features
  - Energy Monitoring
  - Demand Response

Lighting Technology Overview



What's next?

- *Document to be published to CPUC LAP website*
- *Stakeholders use it!*

Nicole Graeber, Senior Development Engineer
negraeber@ucdavis.edu
California Lighting Technology Center
University of California, Davis

Quick Lunch (start at 12:15pm)

ALCS Calculator

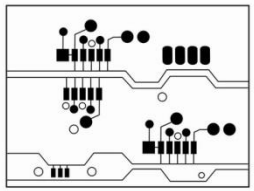
Advanced Lighting Control Systems (ALCS) Energy Estimation Tool

Pacific Gas & Electric Company
Dave Alexander

Together, Building a Better California

ALCS at a Glance

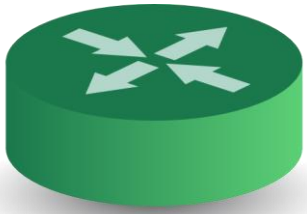
Fixture

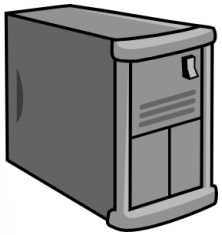


Sensors

Connection/Controller

Network Gateway



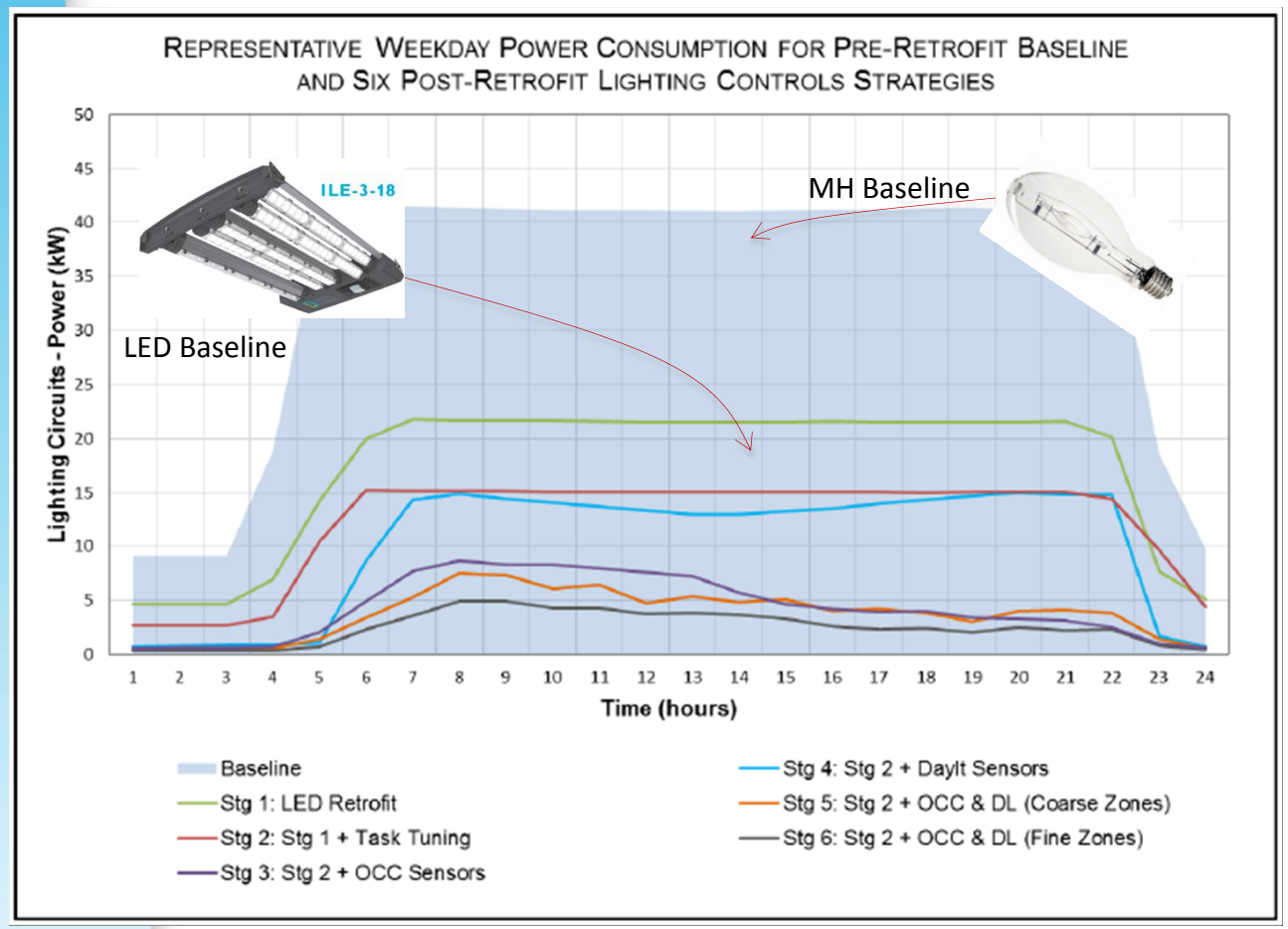


Server

Software

User Interface

ALCS Example – ET Assessment (PG&E)



	% of HID Baseline	% of LED Baseline
HID Baseline	100%	---
LED Baseline (Strategy #1)	51%	100%
Strategy #2	36%	71%
Strategy #3	12%	23%
Strategy #4	28%	55%
Strategy #5	10%	20%
Strategy #6	7%	13%

ALCS Goals

- **Multi-purpose:** Tool can be easily used for the purposes of many stakeholders, including:
  - **Deriving programmatic estimates of savings:** Allows estimates of savings from representative populations of buildings.
  - **Screening of potential projects:** Allows quick screening of potential projects, to determine if further investment is warranted.
  - **Optimizing design decisions:** Allows analysis of detailed site characteristics and control system types to facilitate selection of the highest performing options for a given site.

Known Barriers

Current options for energy savings estimation for an advanced lighting controls program

- Deemed approach
  - Approved estimate limited to occupancy sensors only
  - Single, conservative value underestimates savings in many situations
- Customized calculation approach
  - Requires detailed engineering calculations, simulations,
  - Lack of standard calculation method vary by project
  - Increased cost to program to verify calculations on a case by case basis

What if we could …

- **Have an easy to use calculation tool**
  - That can be used by all stakeholders
- **Predict energy savings from advanced lighting controls**
  - With a standardized, reliable, methodology
- **Develop deeper interest and penetration of Lighting Controls in the market**
  - Allow utility programs across the country to share In the development of ALCS

Will this tool provide “real” savings … ?

A better question would be …

- ***How close*** will this tool be in estimating ‘real savings’ from lighting controls?

And so …

- How should we design tools that allows ***most users*** to get close to the ‘real savings’ for ***every project***?

“Accuracy” can conveniently be a user Problem!

For any engineering calculation tool …

Accurate **INPUTS**

=

Accurate **OUTPUTS**

Calculation Accuracy

- Even with accurate data on all inputs – there is inherent "variability" in any calculation …

PAST Performance

=

FUTURE Results

  - Changes in uses (eg. offices become storage, conf rooms)
  - Climate and weather conditions
  - Changes in occupants with different lighting preferences
  - Changes to commissioning settings, disabling controls

However …

- For most users and most projects
  - Key inputs may be either ***unknown*** or ***unknowable***

So, this tool was designed with a key difference

- "Default values" were provided for ***all inputs***
  - Values based on research or industry standards
  - When users don't know a certain input
  - They simply leave the default value in place

- If and when they have data for that input
  - They can replace default values easily

DEMO Time

Existing Conditions

INPUTS (SCREENING PHASE)

Project Information

Project Identifier (Name)		ABC Inc. Office Building
Street Address		123 A Street
Zip Code	*	94105
City, State		*San Francisco, CA*
Contact Name, Phone		John Doe, (555) 555-5555
Contact email		johndoe@gmail.com
Project ID.		PGE0011022
Project Type	*	Existing Building Alteration
Building Category	*	Office - Small
Building Year Permit Cycle	*	T24-1995 [07/01/1995 - 06/30/1999]

ALCS Trial Strategy

- Gather data to learn if ALCS tool can help deliver the energy savings we seek to meet the goals of CA Lighting Action Plan.
- Validate savings assumptions & accuracy.
- Identify gaps/errors in accuracy.
- Understand Tool's potential barriers to use as a program tool.
- Develop go-to-market strategy & launch.

ALCS Tool Benefits

- Allows program representatives to screen potential sites for those with the best opportunities for savings.
- Allows program participants to easily estimate, and optimize, the value of savings and any available rebates.
- Allows program managers to verify and report claimed savings.
- Allows program managers to estimate the market potential for savings with confidence.

Summary

- The tool has been designed to get better estimates of savings even when inputs are unknown / unknowable
- Relying on well researched “default” inputs allows
  - Ease of use
  - Screening results
  - Reasonable accuracy with few inputs
- The tool will never be 100% accurate … but we can get close
  - With better inputs
  - With data from future field trials

Key Step toward LAP Success

By 2020, advanced products and best practices will transform the California lighting market.

This transformation will achieve a 60-80 percent reduction in statewide electrical lighting energy consumption by delivering advanced lighting systems to all buildings.

Discussion

Define ALCS

- Are we talking about controls only?
- What components make up a system
- Is it the controls that enables savings
- Or the LED fixture that enables controls
- Where do we take Integrated Controls

What's Next

Collaboration

DESIGNLIGHTS CONSORTIUM

PG&E

Questions?

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Pacific Gas and Electric Company
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Pacific Gas and Electric Company
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Together, Building a Better California

Network Lighting Systems

DESIGNLIGHTS CONSORTIUM®

National Approaches to Networked Lighting Systems

DLC's CALC Project and Examples from Outside California

October 20, 2015

Commercial Advanced Lighting Controls Project

DESIGNLIGHTS CONSORTIUM

CALC Project Activities

- Advanced Control Demonstration Projects
- Utility EE Program Specs and Qualified Products List
- Training Programs for Designers and Installers
- Advanced Control Savings Calculator
- Support for Industry Standards
- New Nationally Adopted EE Program Offerings

With Funding Support From:

Burlington Electric Department; Cape Light Compact; nationalgrid; nyserda Energy. Innovation. Solutions.; Eversource; The United Illuminating Company; Pacific Gas and Electric Company; Efficiency Vermont; PSEG Long Island We make things work for you.; neea; Natural Resources Canada / Ressources naturelles Canada; Canada; U.S. Department of Energy

CALC Goal and Objectives

Goal

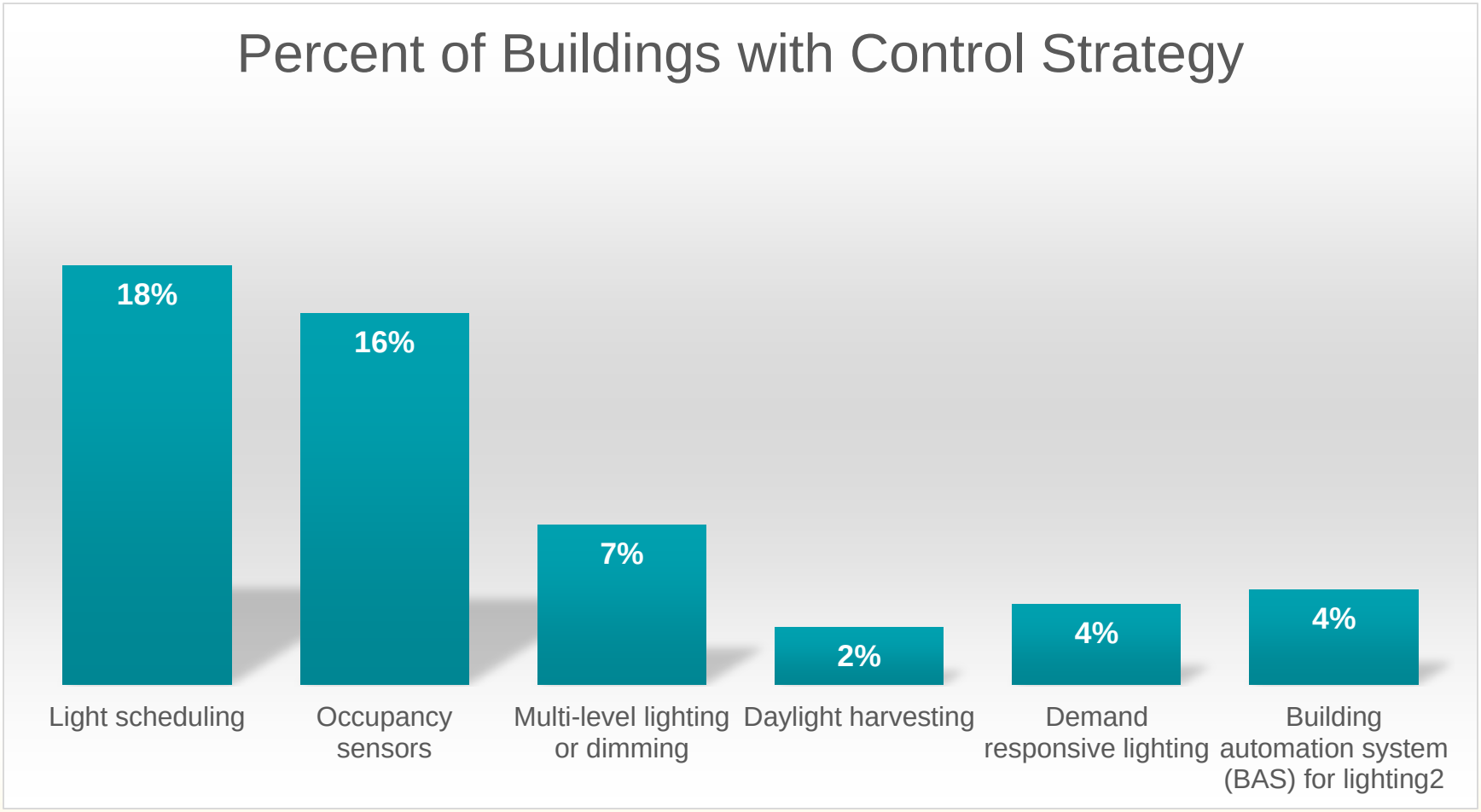
Accelerate Adoption of Advanced Networked Lighting Control Systems

Objectives

Create tools and resources to:

- Reduce or eliminate market barriers that prevent large-scale adoption
- Enable energy efficiency programs to scale up with the technology
- Enable industry to scale up with the programs

Lighting Controls – A Lost Opportunity



Source: 2012 Commercial Buildings Energy Consumption Survey, US Energy Information Administration

Lighting Controls – A Lost Opportunity (California)

DESIGNLIGHTS CONSORTIUM

Table 5-83: Distribution of Businesses by Control Type and EE/DR Participation – Indoor Lighting

Control Type	EE Lighting Non-Participant	EE Lighting Participant	Control Participant	DR Participant
Manual	98%	99%	99%	96%
Manual w/ Occ. Sensor	1.8%	6%	9%	10%
EMS	1.2%	1.7%	0.6%	8%
Photocell & Motion Sensor	1.5%	1.2%	3.1%	6%
Motion Sensor	11%	34%	71%	42%
Continuous On	1.3%	2.6%	4.1%	8%
Photocell and/or Timeclock	3.1%	4.1%	4.2%	12%
Daylighting & Other	0.3%	2.2%	0.3%	4.8%
n	**1,076**	**360**	**139**	**155**

* **The results presented above have been weighted by site weight.** Percentages sum to more than 100% because, for any given participant group, a business may have installed more than one type of lighting control. *n*'s represent the number of surveyed sites included in the analysis.

Source: California Commercial Saturation Survey Report, Itron 2014

Lighting Controls – A Lost Opportunity

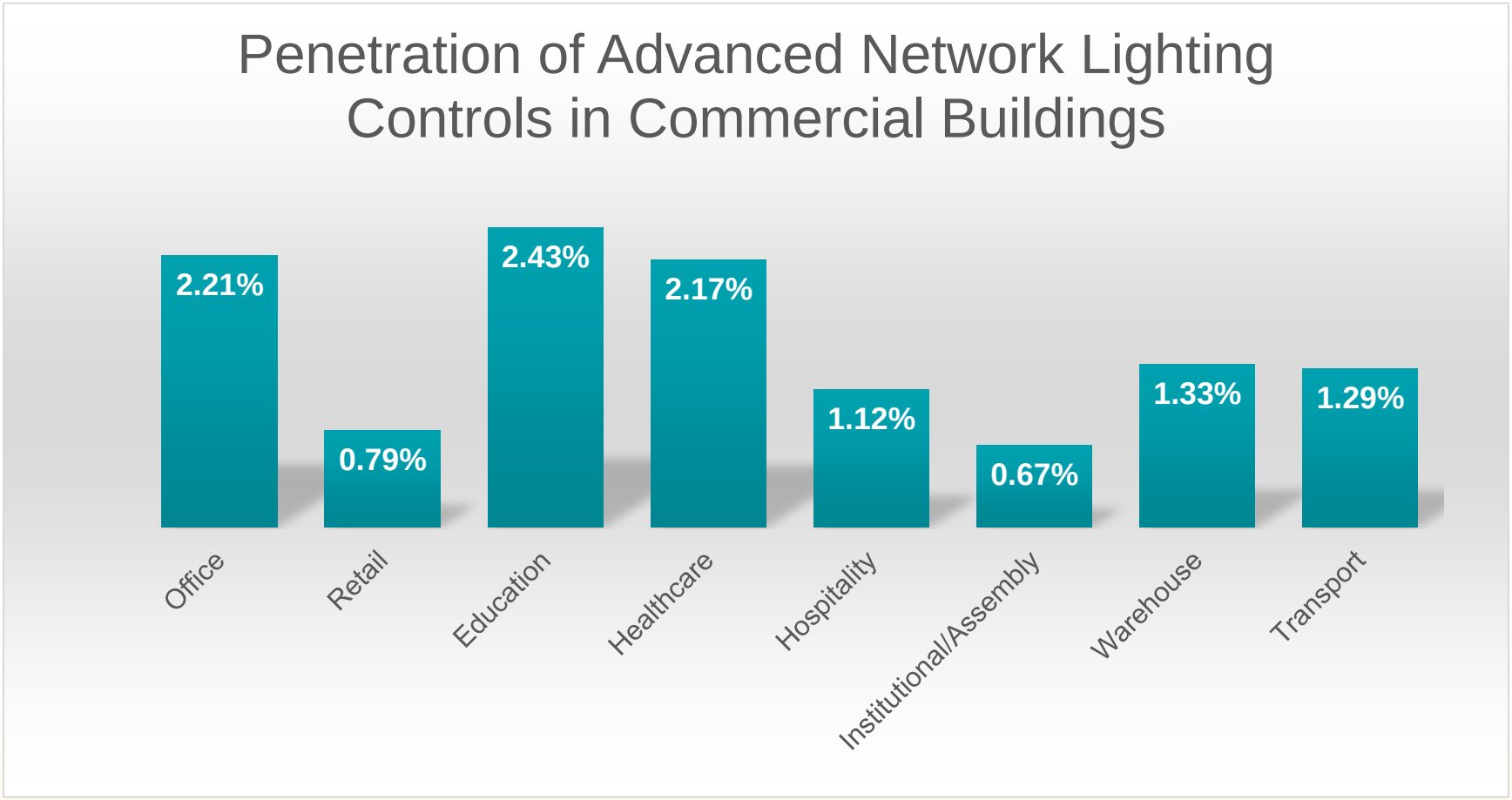
DESIGNLIGHTS CONSORTIUM

Northwest Region Indoor Lighting Power by Control Type and Building Type

Control Type	All (n=791)	Assembly (n=104)	Food Service (n=43)	Grocery (n=69)	Lodging (n=69)	Office (n=113)	Residential Care (n=68)	Retail (n=129)	School (n=72)	Warehouse (n=43)	Other (n=81)
Manual	2,087 73% ± 2%	279 77% ± 6%	53 87% ± 7%	63 72% ± 8%	121 86% ± 3%	448 68% ± 6%	118 91% ± 3%	447 68% ± 7%	139 61% ± 8%	211 83% ± 7%	208 76% ± 6%
Occupancy Sensor	224 8% ± 1%	27 7% ± 4%	0 0% ± 0%	1 1% ± 1%	1 1% ± 1%	73 11% ± 4%	3 2% ± 2%	12 2% ± 1%	34 15% ± 5%	43 17% ± 7%	32 12% ± 4%
EMS System	256 9% ± 2%	33 9% ± 4%	2 3% ± 4%	6 7% ± 5%	0 0% ± 1%	45 7% ± 4%	1 1% ± 1%	120 18% ± 5%	30 13% ± 6%	0 0% ± 0%	18 7% ± 4%
Dimming	24 1% ± 0%	10 3% ± 2%	4 7% ± 5%	0 0% ± 0%	4 3% ± 1%	1 0% ± 0%	1 0% ± 1%	0 0% ± 0%	1 0% ± 0%	1 0% ± 1%	2 1% ± 1%
Timeclock	74 3% ± 1%	7 2% ± 2%	0 0% ± 0%	2 2% ± 3%	2 1% ± 1%	31 5% ± 3%	1 0% ± 0%	28 4% ± 3%	2 1% ± 1%	0 0% ± 1%	2 1% ± 1%
Photocell	13 0% ± 0%	0 0% ± 0%	0 0% ± 1%	0 0% ± 0%	1 0% ± 0%	4 1% ± 1%	0 0% ± 0%	8 1% ± 1%	0 0% ± 0%	0 0% ± 0%	0 0% ± 0%
Other	126 4% ± 1%	5 1% ± 1%	0 0% ± 0%	5 6% ± 3%	0 0% ± 0%	50 8% ± 4%	0 0% ± 0%	33 5% ± 3%	24 10% ± 5%	0 0% ± 0%	9 3% ± 2%
None (Continuous)	54 2% ± 0%	3 1% ± 0%	1 2% ± 4%	11 12% ± 6%	13 9% ± 3%	6 1% ± 0%	6 5% ± 2%	10 2% ± 1%	0 0% ± 0%	0 0% ± 0%	4 2% ± 1%

Source: 2014 Commercial Building Stock Assessment, Northwest Energy Efficiency Alliance

Lighting Controls – A Lost Opportunity



Source: DLC, Navigant Consulting 2014

Lighting Controls – A Lost Opportunity

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- **Utilization of Advanced Network Controls within EE Programs less than 1%**
- **May be better in California due to Title 24 – but not much better…**

Energy Efficiency Program	Number of Projects with ALCs	Total Number of Lighting Retrofit Projects	Utilization Rate
Efficiency Vermont (2011-2013)	<10 (2011-2013)	1,885	<0.5%
Cape Light Compact (2013)	0	291	0%
Burlington Electric Department (2013)	0	Unknown	0%
PSEG Long Island (2013)	<25	5602	<0.5%

Adoption Barriers

- Knowledge and Experience
- Complexity
- Lack of Standardization
- High Costs
- Value Proposition
- EE Program Designs

Commercial Advanced Lighting Controls Project

DESIGNLIGHTS CONSORTIUM

CALC Project Activities

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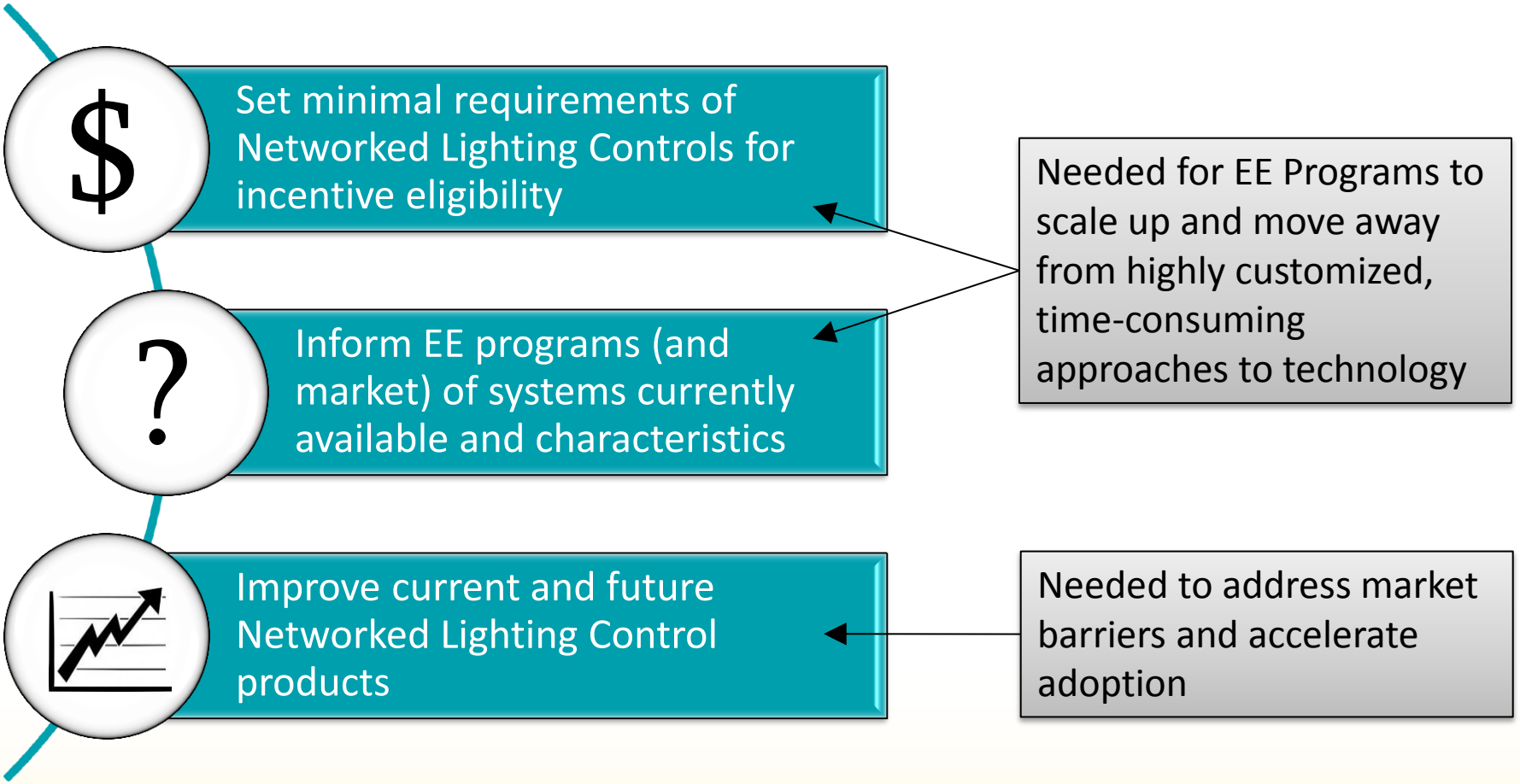
Networked Lighting Control Specs and QPL

Purpose of Specifications and Qualified Products List



Summary of Spec “Required” vs. “Reported” Capabilities

DESIGNLIGHTS CONSORTIUM

'Required' System Capabilities to be listed on the QPL	'Reported' System Capabilities
• *Networked* • *Zoning – Reconfigurable with Layering* • *Occupancy Sensing* • *Daylight Harvesting* • *Task Tuning with High End Tr* • *Continuous Dimming* • *Security* • *GUI*	• *Autonomous / Distributed Processing* • *Luminaire Integration* • *duling* • *nal Control* • *Shedding / DR* • *Plug Load Control* • *EMS/BMS Integration* • *Energy Performance Monitoring* • *Device Monitoring/Remote Diagnostics* • *Operational and Standby Power*

Advanced Control Savings Estimator

Advanced Lighting Control System (ALCS) Energy Estimation Tool

- Built by TRC Energy Services under contract to PG&E and DLC
- Calculates Savings for Layered Control Strategies
- Calculates Savings compared to:
  - Existing Conditions
  - Energy Code Baselines (Title 24, ASHRAE 90.1-2010 or ASHRAE 90.1-2013, IECC 2012 or IECC 2015)
- Phased deployment first to utility programs (2016), then to other interested parties

New Nationally Adopted EE Program Offerings

Nationally Adopted EE Program Offerings

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CONSISTENT:

- Technology Requirements
- Program Requirements
- Training Programs
- Rebate/incentive Methods
- Savings Estimation Methods

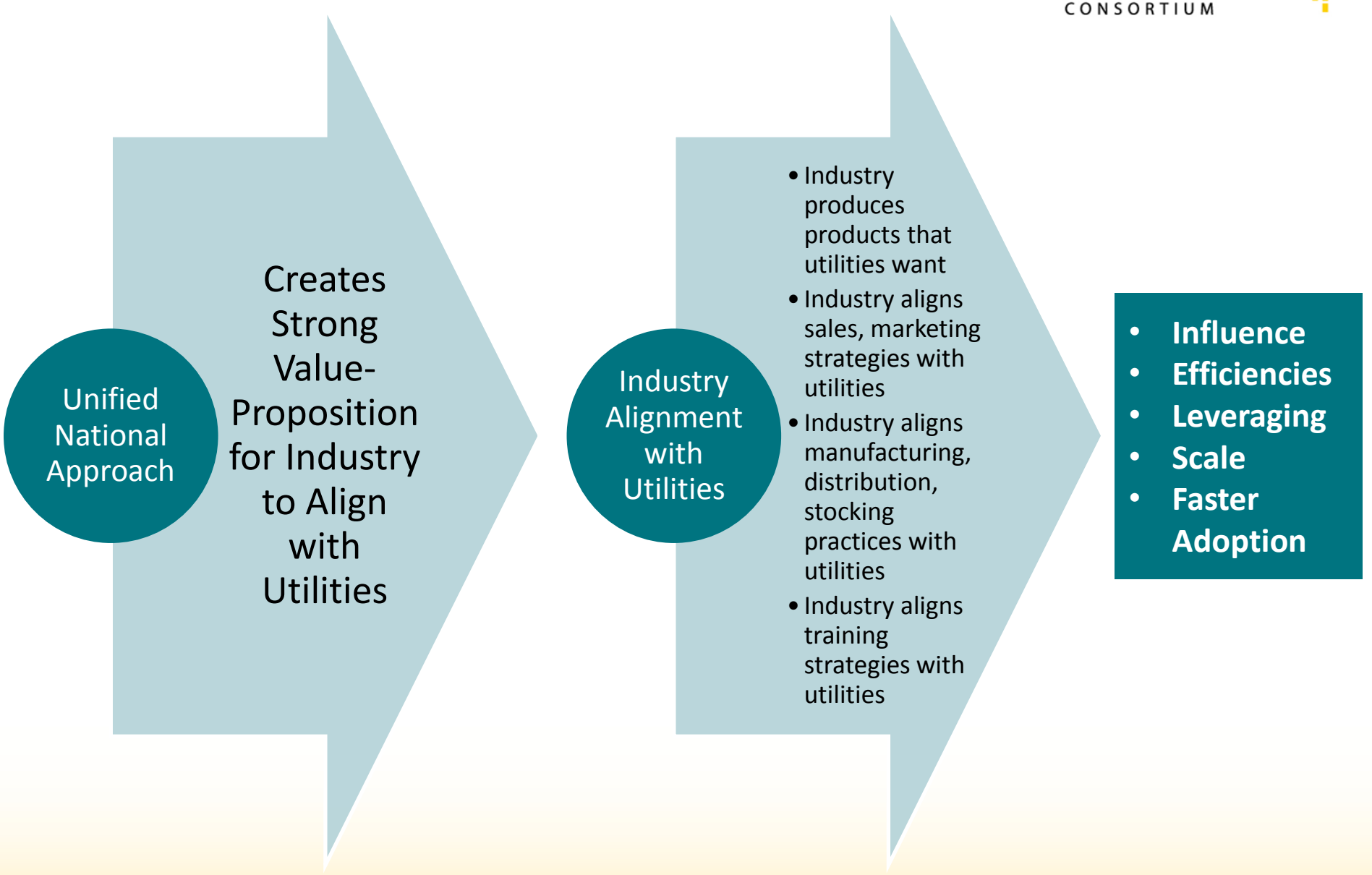
- Enables Scale
- Creates Efficiencies
- Improves Leveraging and Partnerships with Industry

Aligned Objectives

Energy Efficiency Program Industry

Lighting Controls Industry

Increase Sales and Adoption of Advanced Lighting Controls


Unified National Approach
Creates Strong Value-Proposition for Industry to Align with Utilities
Industry Alignment with Utilities
• Industry produces products that utilities want
• Industry aligns sales, marketing strategies with utilities
• Industry aligns manufacturing, distribution, stocking practices with utilities
• Industry aligns training strategies with utilities
• Influence
• Efficiencies
• Leveraging
• Scale
• Faster Adoption

Unified Incentive Strategies – 2 Complimentary Methods

DESIGNLIGHTS CONSORTIUM

High Volume

Easy to use, prescriptive

- System-based for simple or integrated systems
  - DLC per Luminaire incentive PLUS
  - **Additional** per luminaire incentive if controlled by Qualified Networked Control System
  - Deemed Savings if possible

Low Volume

Custom

- Predictable $/ft^2 incentive
- Custom Savings Calculation using new tool
- Reported savings for larger or more complex
- Pay for Performance?
- M&V Required?

Example – Easy to Use, Prescriptive approach

DESIGNLIGHTS CONSORTIUM

High Volume

2015 Lighting – Systems & Sensors Application Retrofit Program

mass save
Savings through energy efficiency

88A	LED Interior 1x4, 2x2 and 2x4 Fixtures and LED Retrofit Kits	**$70**	LED Interior 1x4, 2x2 and 2x4 Fixtures. **Retrofit kits are eligible for this incentive.** Eligible fixtures are required to be listed by the Design Lights Consortium and must meet DLC Technical Requirements #15, #16, #17 or if a retrofit kit #31, #32, #33

Fixture Only

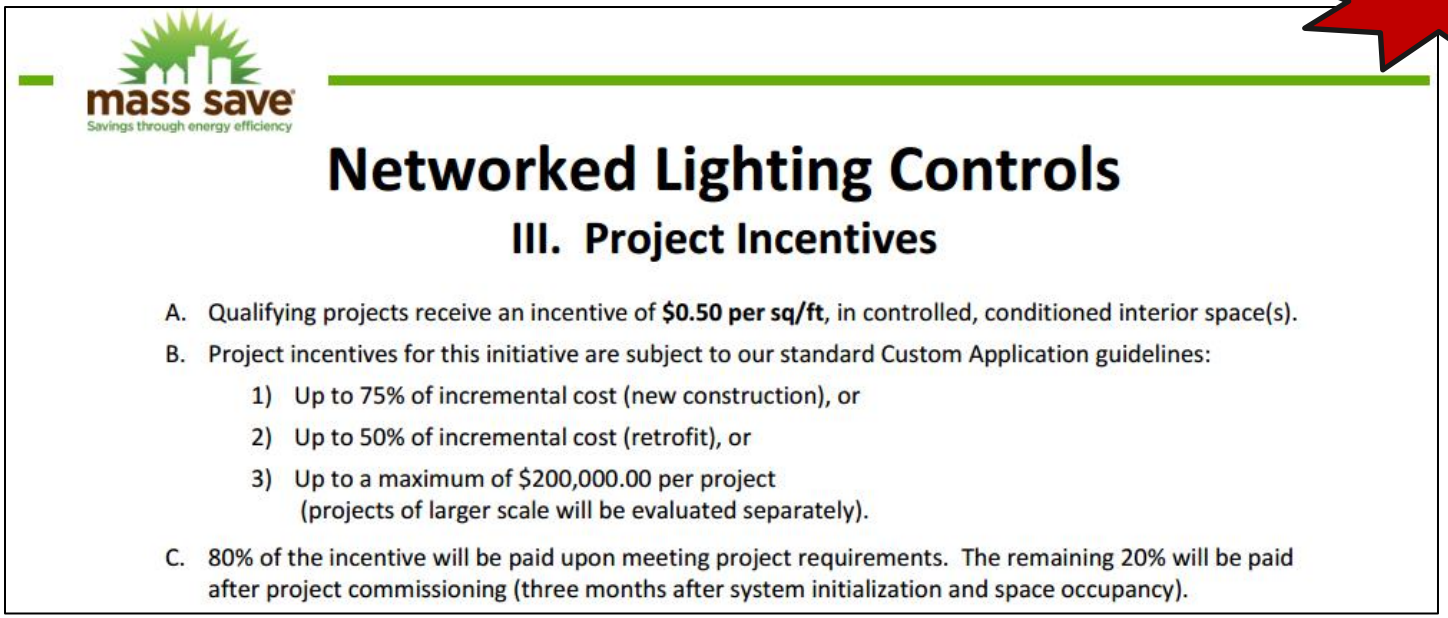
88C	Adaptive LED Interior 1x4, 2x2, 2x4 Fixtures compatible with integral occupancy, photocell sensors and network controls, **measure code 63A**	**$100**	Smart LED Interior Fixtures with integral occupancy, photocell sensors and network controls that are wirelessly configurable and adapt to use patterns. These systems require a remote control or a phone app to initialize, configure and commission. Must fill out table 1C & 1D. Eligible fixtures must meet DLC Technical Requirements #15, #16, #17
63A	Integral Fixture Mounted Dual Sensors and Controllers.	**$50 (per fixture)**	Integral fixture mounted dual sensors able to be programmed, configured, networked, and addressable. With motion and photocell/ambient light sensors along with embedded programming. System to control motion response, illumination levels and scheduling. Only one incentive per networked fixture.

Fixture + Integrated Sensors & Networking

Example – Custom Approach with Predictable Incentive

DESIGNLIGHTS CONSORTIUM

Low Volume



mass save
Savings through energy efficiency

Networked Lighting Controls

III. Project Incentives

A. Qualifying projects receive an incentive of **$0.50 per sq/ft**, in controlled, conditioned interior space(s).

B. Project incentives for this initiative are subject to our standard Custom Application guidelines:

1) Up to 75% of incremental cost (new construction), or
2) Up to 50% of incremental cost (retrofit), or
3) Up to a maximum of $200,000.00 per project (projects of larger scale will be evaluated separately).

C. 80% of the incentive will be paid upon meeting project requirements. The remaining 20% will be paid after project commissioning (three months after system initialization and space occupancy).

- http://www.masssave.com/~/media/Files/Business/Lighting-Controls/MassSave-Network-Lighting-Controls_Project-Requirements.pdf

Other Examples – Custom Approach

Advanced Lighting and Controls Pilot Program

LINCS Pilot

- Angi Xanders of DNV GL will talk more about these…

Our Vision

By 2020…

- Every luminaire seen by EE programs is controlled
- Networked controls required for the vast majority of projects to receive incentives
- Majority of luminaires are shipped from factory with embedded sensors, intelligence, networking (and meter?)
- Technology, installation cost and complexity dramatically reduced
- Market actors knowledgeable and skilled
- M&V is automated
- Consistent EE programs, strong industry partnerships

Thank You!

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Lighting & Advanced Controls Pilot Programs for AEP Ohio and Consumers Energy
(Ohio and Michigan)

Angi Xanders, DNV GL

October 20, 2015

Lighting Action Plan Workshop

AEP OH ALC Pilot Program

2014

- Prime the market
- Few projects, considerable outreach

2015

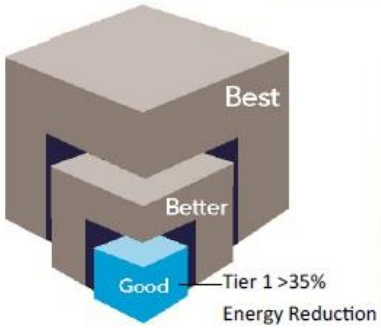
- 14 projects expected to be completed by year end
- Extensive training

2016

- Analyze results of completed projects
- Adjust incentive structure if required
- Continue training

AEP OH ALC Pilot Program – Tier Structure

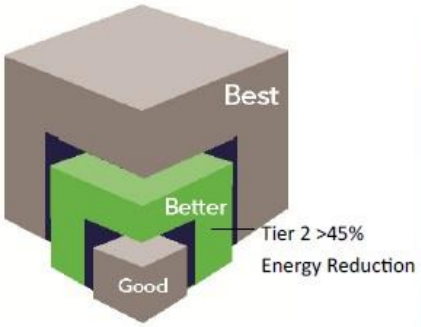
Advanced Lighting System Controls



Tier 1—Good

Existing Luminaires with minor modifications required (already equipped with step-dimming, or inboard/ outboard ballasts or drivers). Control via switching:

- Occupancy/vacancy sensing
- Daylighting
- Demand Response (utility Driven)
- Load Shed (Facility Driven)

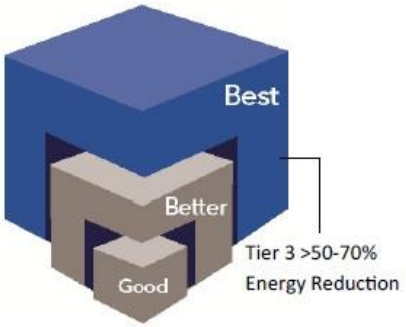


Tier 2—Better

Existing luminaries, lamp and ballast retrofit for control via full dimming:

-Control strategies listed in Tier 1 via dimming vs switching for less disruption to occupant, plus:

- Lumen Maintenance
- Personal Control
- Task Tuning



Tier 3—Best

New luminaries/LED retrofit kit + granular control, and capable of all control strategies

-All control strategies listed in Tier 2, plus:

- Reduced lighting power density at full output
- Optimal fixture types and locations
- IES recommendations for reduced glare, increased occupant comfort and productivity

All tiers include network controls with adjustability of occupancy sensors and photo sensors settings, scheduling capacity, outage and energy-use reporting.

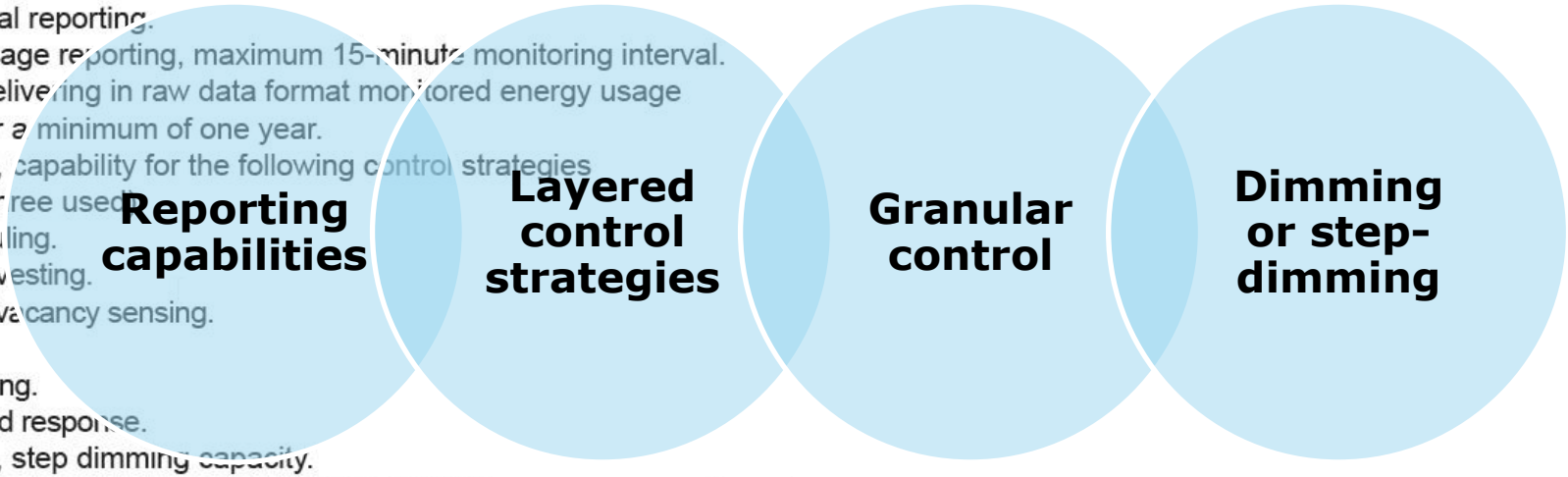
AEP OH ALC Pilot Program – System Capabilities

SPECIFICATIONS

An advanced lighting and control solution incorporates the installation of the most efficient lighting sources available with a fully networked dynamic control solution. This approach affords the highest level of user interface, control and reporting to maximize occupant performance and comfort while providing the most significant overall energy-saving potential available.

The networked lighting control system shall have the following minimum capabilities:

- A central master programming, control and reporting interface that is connected via hardwire or wireless technology to all devices and luminaires throughout the entire system. At a minimum, the networked lighting control system shall be capable of the following:
  - Providing complete programming and control from the central location.
  - Reporting capability.
    - Occupancy reporting.
    - Operational reporting.
    - Energy usage reporting, maximum 15-minute monitoring interval.
- Storing and delivering in raw data format monitored energy usage information for a minimum of one year.
- At a minimum, capability for the following control strategies (minimum of three used).
  - Time scheduling.
  - Daylight harvesting.
  - Occupancy/vacancy sensing.
  - Task tuning.
  - Load shedding.
  - Auto demand response.
- At a minimum, step dimming capacity.
- At a minimum, small zone control capability (16 fixtures per zone or fewer).
- Remote interface and control, such as BACnet, LONworks, etc.



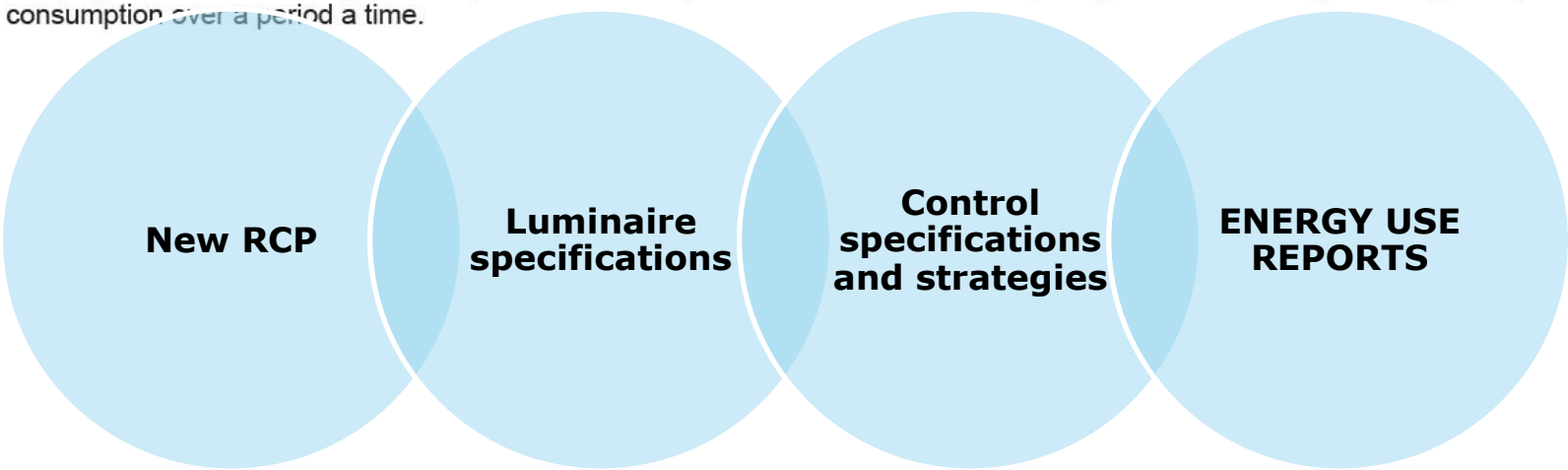
AEP OH ALC Pilot Program – Required Documentation

Advanced Lighting Controls
Application

AEP OHIO®

Post-installation information needed for Final Application:

- New reflected ceiling plan.
- Lighting inventory spreadsheet, and lighting fixture and controls specification sheets (if these deviate from the Pre-Approval Application).
- New fixture operating schedules and control strategy.
- Specification sheet for proposed control system and scope of work indicating the advanced lighting controls strategy.
- Raw data file with kW, watts or voltage, and amperage readings in an Excel spreadsheet. The metered data should have a maximum of 15-minute intervals over a minimum of a two-week period.
- The project is deemed ineligible if the post-installation system does not have the capability to record and report the system power consumption over a period a time.



AEP OH ALC Pilot Program – Incentive Structure

Installation Type	Incentive Tier	Project Incentive Rate ($/ft²)
Lower Lumen fixtures/Higher Fixture Density (e.g. office, classroom)	1	$0.30
	2	$0.65
	3	$1.50
Higher Lumen Fixtures/Lower Fixture Density (e.g. warehouse, manufacturing, gymnasium)	1	$0.15
	2	$0.25
	3	$0.45

Note: The AEP Advanced Lighting Controls Team will determine the appropriate incentive tier for the project during the Pre-Application review process.

Consumers Energy's ALC Pilot Program

Phase:

Pilot – Launched January 2015

Incentive structure:

$0.26/kWh

- Base incentive ($0.08/kWh)+ ALC bonus ($0.18/kWh)

2016 Target:

10 new customers

Outreach

- Engaged with Trade Allies, manufacturers, customer account managers
- Initial market entry based on relationships and face-to-face meetings

Advanced Lighting & Controls Training

Webinar series

- #1: **Introduction to ALC**

Introduces advanced lighting systems, the capabilities and benefits beyond energy savings, & encourages a long term investment view. Explore improved ROI & learn about AEP Ohio's incentive program for this technology.

- #2: **ALC – Technical**

Topics include LED evaluation: thermal management, color, and glare control using LM-79, LM-80, TM-21 and photometric reports. Deep dive into control strategies and components.

- #3: **ALC – Sales**

Knowing how to sell an advanced lighting system is the final component. This session includes sales & marketing strategies, case studies, and a deep dive into the documentation required to receive an incentive.

Advanced Lighting & Controls Training

Half-day workshops

Both utilities are offering personal workshops to firms that specify lighting and controls

- Focus on specific project details
- Intensive training on various manufacturer product offerings and capabilities
- Overview of how to use lighting analysis software

Questions?

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SAFER, SMARTER, GREENER

Breakout Sessions

Report out

Wrap-up